Vermont Residential and Regulated Composting Practices: A First Look at Lead Contamination

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Authors:
Kurt Alles
Forrest Carroll
Hannah Dietrich
Teddy Kuo
Gina Puccinelli

Executive Summary

This paper reviews the procedure and results from an investigation of lead contamination in residential and regulated composting facilities throughout Vermont. The investigation was designed and conducted by the Middlebury College ENVS0401 “Black Gold” team and was part of a larger project assessing different conduits for lead exposure that was motivated by an interest expressed by the Vermont Department of Health. From running an analysis on 42 household samples, the team found wide variations in lead levels ranging from “not-detectable” to over 4,500 ppm in one extreme case. Due to the limited sample size of residential samples, the group was hesitant to draw any definitive conclusions but discussed the results from two different exposure pathways and their remediation strategies. Our household data indicating the potential for lead contamination in compost prompted us to produce educational materials for the public to reduce their exposure. From our analysis of historical data and field studies of local composting facilities we conclude that lead contamination in regulated facilities is not an issue, and Vermont facilities seem to have already put in place measures to manage a contaminant like lead. In recognizing the advantages of encouraging sound composting practices both on the residential scale and larger facility scale, Vermont passed Act 148: Universal Recycling and Composting Law, a comprehensive ban on all recyclable and organic materials from entering Vermont’s only landfill. We then conducted a policy analysis of Act 148 to examine the implications and any unforeseen issues with the law.

Keywords: *Lead, compost, behavioral study, soil contamination, blood lead levels, Act 148*

Glossary of Terms:

ANR	*Agency of Natural Resources. The Agency responsible for the implementation of Act 148 and the associated rule-making requirements.*
CDC	*The Center for Disease Control*
CPSC	*Consumer Product Safety Commission*
CSWD	*Chittenden Solid Waste District*
DSM Report	*DSM Environmental Services Report on the implementation and implications of Act 148*
HHLPPP	*Healthy Homes Lead Poisoning Prevention Program*
MMP	*Vermont’s Material Management Plan*
SWME	*Small Waste Management Entities*
NMOCs	*Non-Methane Organic Compounds*
VDH	*Vermont Department of Health*

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Lead

Background

Over the last four decades, scientifically informed US federal and state legislation, as well as increased public awareness, has helped curb the entrance of lead into the environment. Even with the significant progress that has been made however, lead, which is a naturally occurring, persistent heavy metal is still the source of chronic and acute human health problems (US EPA, 2013). EPA standards have determined that compost with under 400 ppm of lead are deemed acceptable. However, according to the Vermont Agency of Natural Resources' Department of Environmental Conservation, this level is 300 ppm (Vermont Agency of Natural Resources, 2012).

Health Concerns

For those who have been exposed, lead does the most damage to the central nervous system as well as brain functions (Chen, 2013). As with many toxic substances, the risk of negative effects is amplified in children under six years old because of the physiology of their developing neurological pathways. There is no blood level of lead in the body that has been deemed "safe," however there are levels below which the federal & state governments deem acceptable (Lead Safe Vermont, 2014). The Vermont Department of Health recommends venous sampling if capillary blood lead levels are $\geq$5 µg/dL (Vermont Department of Health). Additionally, the Vermont Department of Health suggests recommended venous testing windows depending on the severity of blood lead levels through capillary testing as shown below.

Table 1: Capillary Blood Lead Level results and suggested venous confirmation testing window (Vermont Department of Health, 2008).

Capillary Blood Lead Levels	Confirm With Venous Test Within
5 - 9 µg/dL	3 months
10 - 44 µg/dL	1 month
45 - 59 µg/dL	48 hours
60 - 69 µg/dL	24 hours
70 + µg/dL	Immediately as an emergency test

*Note that the higher the capillary test result, the more urgent the need for a confirmatory venous test.

In children, chronic exposure to lead (Pb) that is above 5 µg/dL can reduce intelligence quotients, cause hyperactivity, shortened attention span, as well as impair physiological and physical growth (Chen, 2013). Research has also demonstrated a correlation between high lead levels and high rates of violent crimes, lower IQ, and cases of ADHD (Drum, 2013). There is no medical treatment for the poisoning that can result from low-level exposure. At low levels of

exposure, the symptoms of lead poisoning are difficult to detect and impossible to attribute to lead poisoning without proper testing. In severe cases lead poisoning problems manifest themselves in mental retardation, convulsions, comas, and even death.

Pathways of Exposure

In Vermont, the most common source of lead poisoning comes from lead paint chips and paint dust that are released into the interior and exterior home environment through chipping and peeling paint (National Center for Healthy Housing, 2014). Other sources include lead residuals in soil that can be traced back to the widespread use of leaded gasoline in the 1970s (US EPA, 2013). Although leaded gasoline has since been banned, the effects are still seen because of lead's persistent chemical quality. Because Pb is an element, it does not degrade over time and will remain in a physical environment for years after introduction (US EPA, 2013).

Lead in soil has the potential to leach and spread into adjacent environments, contaminating nearby water, air, and other mediums (US EPA, 2013). Dust from lead-containing soil or from lead paints can be mobilized in surrounding air or water and be transported for miles before deposition. Due to these mobility characteristics, lead from both paint and gasoline residuals can contaminate both soil and compost (Goldstein, 2012).

Bioaccessibility and Bioavailability

Absolute levels of lead in a physical environment do not directly correlate with the lead that is available for human biological uptake (Clark, 2008). The concept of bioaccessibility explains how only a fraction of the chemical dose of lead that a person is exposed to will be absorbed and reach the circulatory system (Ruby, 2000). Bioavailability, explains that even once introduced into the circulatory system, a smaller proportion of that lead is liberated in biological fluids, and becomes available for absorption (Clark, 2008). It is the final extent of this bioavailability that truly determines the toxicity of lead, and dictates the effects and impacts of that exposure. Differences in physical and chemical characteristics of a lead-laden environment change the degree to which Pb is bioaccessible and bioavailable, and therefore influence absorption and health risks. The nutrition status of the individual in question also plays a factor in how detrimental lead exposure will be. Healthier individuals with nutrient-rich diets will absorb less of the lead they are exposed to than people with (broadly-defined) unhealthy eating habits.

Legislation

In 1978, the Consumer Product Safety Commission (CPSC) issued a final ban on lead-containing paint. Up until that point, the CPSC had permitted a 0.5 percent lead content maximum but in order to conform to the Lead-Based Paint Poisoning Prevention Act, dropped that maximum to 0.06% (CPSC.gov). Lead hazard reduction was (and still is) primarily realized through three federal statutes: first, the Lead-Based Paint Poisoning Prevention Act of 1971; second, the Lead Contamination Control Act of 1988; and lastly, the Residential Lead-Based Paint Hazard Reduction Act of 1992 (part of the Housing and Community Development Act). Of these three laws, the last is the most meaningful for Vermont because it explicitly addresses the need for mitigation of the lead health risks associated with old (pre-1978) housing stocks. The Residential Lead-Based Paint Hazard Reduction Act laid out a framework for states to control lead hazards and mandated that states adopt certain training programs in risk assessment, inspection, and abatement (Farquhar, 1994).

Over time, the refinement and development of many federal and state lead laws have shifted focus from reactionary to preventative. (Title 18, Chapter 38). In 1994, when Vermont passed its first lead hazard reduction legislation, the Center for Disease Control (CDC) had projected that $80 billion (modern day value-conversion) would be needed to remove and stabilize lead-based paint across the US (Ibid). Over the following few years, part of those (startlingly expensive) remediation efforts were outlined in Vermont legislation. Title 18 Chapter 38 of the Vermont statutes lays out a very specific strategy intended to prevent further harm via lead poisoning. The different sections of the law cover the prevention role that *Public Education* will play (§1754); outline the emphasis put on *Universal Screening* efforts (§1755); explicitly charge the commissioner with making sure that tested children who return positive for elevated BLL (10 or more micrograms of lead per deciliter of blood) obtain a confirmation test and follow through with other necessary measures (§1757); and provide extensive guidelines for *Essential Maintenance Practices* (§1759), among other preventative measures.

In 1994, the law required all children of one and two years of age be tested for elevated blood lead levels (BLL). At that time, the blood lead level of concern was 10 micrograms lead per deciliter of blood. In 2007, the Vermont Department of Health decided to increase the stringency of their level of concern by setting the level at 5 µg/dL. In 2008 Ginny Lyons drafted Bill *S.0152*: *Prevention of Lead Poisoning by Exposure to Lead in Consumer Products*, which was passed into law the following year. This Law states that if providers did not reach their benchmark testing of 85% of 1 years olds and 75% of 2 year olds, the testing would be run by government agencies at state costs. Table 2 below from the Childhood Lead Poisoning Prevention Annual Report (2013) shows the most up-to-date data on elevated BLL in high-risk populations:

Table 2: Blood Lead Tests and Results for Vermont Children (ages 0-6 years, 2013, Vermont Department of Health. 2013).

Age	Population	# of Tests	% Tested	# <5 µg/dL	% < 5 µg/dL	# 5-9 µg/dL	% 5-9 µg/dL	# ≥10 µg/dL	% ≥10 µg/dL
Under 1	5,895	355	6.0%	328	92.4%	21	5.9%	6	1.7%
1	6,088	4886	80.3%	4486	91.8%	352	7.2%	48	1.0%
2	6,217	4296	69.1%	3985	92.8%	275	6.4%	36	0.8%
3	6,449	399	6.2%	341	85.5%	48	12.0%	10	2.5%
4	6,566	203	3.1%	173	85.2%	26	12.8%	*	*
5	6,681	106	1.6%	88	83.0%	17	16.0%	*	*

Protocol for Dealing with Lead Exposure

Today, the VDH does case management at venous confirmed blood lead levels of 10 µg/dL or higher. When confronted with venous confirmation between 5-9, a phone call is made to the family to inform them of the result. The Vermont Housing and Conservation Board (VHCB) has played an instrumental role in helping the State meet its §1759 Essential Maintenance Practice (EMP) goals by offering EMP certification classes to landlords, child care providers, and contractors. In Vermont, a few Department of Housing and Urban Development (HUD) grants, written under the Lead Safe Housing Rule, have helped establish and sustain

programs such as the Burlington Lead Program (BLP). The BLP is intentionally linked to the City's Community and Economic Development Office (CEDO), giving them proximity and access to other programs that now have greater social and economic interests in lead hazard reduction.

For the purposes of this paper, another important rule to understand is the EPA's Renovation, Repair, and Painting (RRP) Rule, the implementation of which is up to the State (Environmental Protection Agency, 2014). In accordance to the Federal RRP Law, the Vermont state program must be at least as protective as what is outlined in the federal RRP. The primary concern is "adequate enforcement" of the RRP Law. In general, the Vermont program—again with funding from HUD—provides technical and financial assistance to property owners to reduce hazards from lead-based paint. Since 1995, the Program has provided assistance to control lead hazards in over 2000 homes and apartments throughout Vermont (VHCB, 2012). Following Section 18 Chapter 38 of the state statutes, priority is given to homes that have lead poisoned child occupants.

Health department professionals and policy makers are always thinking of programs, incentives and policies that further reduce child exposure, and risk of exposure, to lead. Most of the time, agencies like the VDH face budgetary constraints that restrict them from increasing their capacity for testing, hiring case managers, upgrading databases, and increasing targeted public outreach and awareness (Haugen, Personal Comm., 10/23/2014). While policy recommendations are not intended as the focus of this report, it is important to keep in mind the room for improvement for lead hazard reduction in Vermont. An analysis of a 2006 report by the Dartmouth Center for Evaluative Clinical Sciences, highlighted a few well-conceived policies for next steps regarding Vermont's lead abatement initiatives. These include: "Balance funding and enforcement measures to encourage participation of citizens and property owners; Engage stakeholders by diffusing the impact of remediation costs; and mandate presale lead inspection of all Vermont real estate." (Dartmouth Center for Evaluative Clinical Sciences, 2006). Unlike California, Maryland, and a few other States, Vermont does not yet require its health care service plans or insurance policies to cover blood tests for lead. Because Vermont has no parallel requirement, it relies on insurers to voluntarily cover blood lead tests and treatment.

Lead in Compost

The idea of lead exposure through interaction with soil and compost is a relatively new concept for both the State and Federal Health Departments. The impetus for this discussion and analysis in Vermont comes from a few different sources, the first being a very tangible problem faced by a municipal composting facility in Boston, MA.

Boston: A Case Study

Since the inception of Boston's large-scale municipal composting facilities, urban gardeners have been able to avoid relying on city topsoil—which in many places of the city has unsafe level of lead—by incorporating organic waste locally. But in 2012, researchers began to realize that the free compost they were using might come at a cost (Pfeiffer and Jolicoeur). We know from the research of our peers that the highest concentrations of lead are usually along the drip lines of homes, where deposits of exterior paint can accumulate, or along roads where lead would precipitate out of leaded gasoline exhaust (Pei and Chaolin, 2004). For more information on lead in Vermont soil, please see the report on the 2014 ENVS401 project archive website entitled "Soils as an Exposure Pathway for Lead in VT". In the case of Boston, it was the former

avenue of introduction that caused the facility so much trouble. From 1995 to 2012, the city of Boston saw an increase of nearly 10,000 tons of leaf, branch/shrub and grass waste, due in large part to a state regulation that banned that type of organic matter from going to landfills/garbage incinerator plants (Abel, 2013). Instead, that waste was directed to composting facilities, and much of it contained dust and chips from lead paint that had been raked up from urban yards and transported to the facility. This particular facility in Mattapan, was overseen by Apple D'Or, a Southborough-based waste management contractor (Abel, 2013).

What was shocking was that, "some samples taken this year showed concentrations of as much as 480 parts per million of lead. The city's mean lead concentrations [in 2012] were 299 parts per million." While some people claim that the compost is the root of the issue in Boston, one of the main ideas of raised beds and bringing in top soil (usually in the form of compost) is supposed to ameliorate the risk of exposure to contaminated soils. Organizations in Baltimore, MD, like the Community Greening Research Network, bring in topsoil for their urban gardening projects in an effort to avoid the contaminants that inevitably are present in the ground. That said, even "clean" dirt that is brought in can be contaminated within a few years by chipping and peeling paint, dust from neighboring contaminated soils, or translocation via storm water, etc. The Boston case was an anomaly, and even the highest levels found during the increased testing in 2012 were just above the federal maximum recommendations. While some municipal compost facilities have experienced problems with other contaminants, lead has never been an issue on a municipal scale in Vermont.

Differences in Context (urban vs. rural)

Because of the prevalence of lead in the environment, all people are at risk of exposure to lead. The second National Health and Nutrition Examination Survey (NHANES II) investigated typical levels of lead exposure for the United States population. In order to investigate lead exposure on a national scale, measurement of blood lead was included in the survey. NHANES II established the distribution of blood lead levels for the United States population during the period 1976-1980 and demonstrated clearly that urbanization was associated with an increased prevalence of elevated blood levels (Yankauer, 1983). While ingestion of lead paint chips and dust has been considered the primary mode by which children consume lead in high quantities, Johnson *et al.* 2006 looked past paint and conducted an investigation of lead concentrations in inner-city garden soils. While it is known that soils around lead smelters and major roadways have high lead levels, Johnson and his colleagues demonstrate in their investigation that garden soils from an entire urban area are consistently and heavily contaminated with lead. In order to insure that the samples were "well-mixed", Johnson and his colleagues took samples of soil that had been mixed to a depth of 20cm-30cm. This ensured that high lead concentrations, if found, would be evidence of the pervasiveness of lead in urban areas. As a result of this sampling technique, the study concluded that the high concentrations of lead could not be coming from paint dust alone and uncovered a general urban pattern that is consistent with uses of leaded gasoline and traffic density (Mahaffey, 1983).

Because urban soil has, on average, higher lead concentrations than rural soils, urban compost bins are more likely to contain dangerous levels of lead if homeowners and renters compost their yard and garden debris. This yard and garden debris will naturally introduce soil with high lead concentrations to the compost by transferring this soil from the yard into the compost bin.

While a potential source of lead exposure, compost can also be used to stabilize lead in

the soil environment. Since lead mobility is increased when the pH of soil is low, compost can reduce the movement of lead in soil because of its ability to raise the pH of soil (Doyle, 1998). The increased stabilization of lead in soil due to compost additions will limit lead dust particles from becoming airborne. Therefore, lead stabilization in soil will limit both its spread to other environments and its exposure to humans.

Vermont Composting Facilities

With sixteen medium to large public and private composting facilities, Vermont is a composting leader among small states. Facilities like Vermont Natural Ag Products on the Foster Brothers Farm, where the Foster family has been producing compost for the agricultural community for 25 years, epitomize the sustainable and entrepreneurial spirit of the state. Then there is GROW compost, owned and operated by Lisa Ransom and Scott Baughman, who have made their home on the forty acre plot where they also produce nutrient rich compost from institutional, agricultural, commercial, and residential residuals. These facilities value quality over all else and with this dedication they test for and take precautionary measures against contaminants like lead, plastics, and herbicides. Although compost facilities have tight margins, composting can be a lucrative industry; some compost facilities bag their compost and sell their products across New England, while others have more informal composting pickup stations where the local small farm or gardener can haul away a truckload. Although these facilities make a living on their compost, they also all value the ethics behind their work. Their ethics are composed of tenets of environmental stewardship, the support of small Vermont agriculture, and reuse. Many of these beliefs are shared at the state level as exemplified by recent composting legislation.

With Vermont's sixteen compost facilities, the state still only diverts a fraction of the organics from Vermont's waste stream. Organics made up 28% of the state's waste in 2012 (MMP, 2013). In 2012, Vermont's legislature attempted to address this resource loss when they unanimously passed Act 148, also known as the Universal Recycling and Composting Law, which bans all recyclable and compostable material from entering the landfill by 2020. A bold and ambitious law, Act 148 sets a series of benchmarks between 2014 and 2020 that progressively target and enforce bans on waste producers, starting with large business and institutions and ending with Vermont residents. In the latter half of this paper, we will delve into Act 148 in greater detail.

Methods

Households

We decided to analyze the prospect of lead in compost on two different scales: home composting and large-scale composting facilities. In order to gather information about household composting piles across the State, we first designed a survey directed at homeowners to gather some background information on composting habitats and to identify potential households that would be willing to have samples taken from their mature compost (i.e. compost that has fully decomposed into a dark, nutrient rich black soil). Our survey included questions about compost composition, characteristics, use, and location (Appendix 1).

We posted the survey on both Burlington and Middlebury Front Porch Forum sites where our survey generated 99 responses, and resulted in 32 different compost samples from 19 residential compost bins. The locations of these samples range all the way from Brattleboro to Winooski (Figure 1).

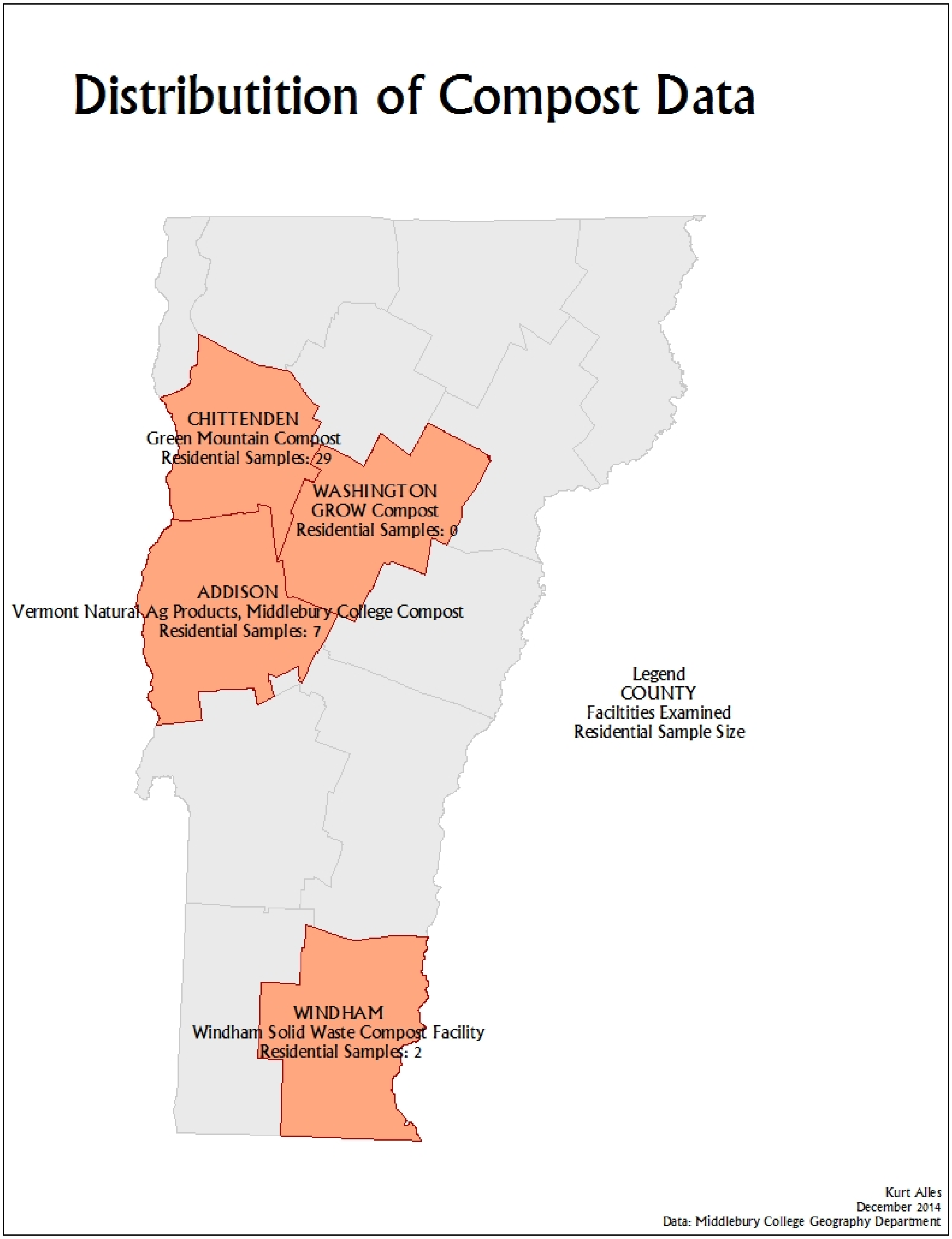

Figure 1: Distribution of sample collection and compost facility research by county.

Compost was collected from each residential compost pile with a hand trowel and placed into labeled plastic bags. We washed the trowel after each collection to prevent cross-contamination of our samples. We then tested lead levels in all 32 of our samples using X-ray

Fluorescence (XRF) analysis. 28 of our original 32 samples underwent further testing by the students in CHEM0311, a Middlebury College course taught by Molly Costanza-Robinson and Jim Larrabee. The CHEM0311 students analyzed these samples using Graphite Furnace Atomic Absorption Spectrometry (GFAAS). XRF and GFAAS analysis are both commonly used to determine heavy metal concentrations. GFAAS is an effective method with low detection limits but it requires the use of long acid digestion times. XRF analysis has traditionally been viewed as a less sensitive method, but the analysis can be performed both in and ex-situ. We used two methods in order to establish a more accurate understanding of lead levels in household compost. Both methods used to test for lead levels in compost had the same preliminary steps, described below.

First we recorded weights for roughly 12 to 16 grams of the wet compost. Then we placed the wet samples into an oven for 18 hours at 120 degrees Celsius to dry them. We then weighed the dry samples to determine how much moisture was lost, since our results were in dry-weight. The next step to prep for the XRF analysis involved crushing the samples with a mortar and pestle to homogenize the sample. Then we sifted the compost through 3 layers of sieves to collect the finest-grain particles. Using a funnel we carefully packed these particles into plastic containers with a plastic film on top. We then covered the packed particles with a round piece of paper to prevent the particles from moving. We then placed cotton between the piece of paper and the top of the plastic container to hold the particles down. The prepped samples were then analyzed with the XRF, which ran for 30 source seconds per sample (approximately 2 minutes in real-time) and gave us lead readings in ppm. These prepped samples were then used by CHEM0311 for the GFAAS analysis. In this analysis, lead concentrations were determined using a PerkinElmer AAnalyst 600 (Waltham, MA, USA) graphite furnace atomic absorption spectrophotometer operated according to the manufacturer's recommended settings for lead. A diluent of 0.2% nitric acid was used as a blank and to make a non-linear forced through zero calibration curve with points at 10, 25, 50, 75, and 100 ppb. A matrix modifier of 3 μg $Mg(NO_3)_2$ and 50 μg $NH_4H_2PO_4$ was used for each sample and standard. The CHEM0311 students performed the same analysis on four reference Road Dust samples, (BCR-773, 866 ± 16 ppm) and the average concentration was 830 ppm (96% recovery), thereby validating the analytical methods (further details on this chemical analysis can be found in the appended paper in the "Further Reading" section entitled "Determining the presence of lead in soils and compost by Graphite Furnace Atomic Absorption Spectrometry and X-Ray Fluorescence," written by Kate Bauman, CHEM0311, 2014).

Facilities

In order to examine composting on a larger scale, we first identified the certified composting facilities across the state of Vermont (Table 3). These regulated facilities are required to receive certification from the state based on their size and output, and are categorized into different classes (Table 4). There are also informal composting operations in Vermont. Any facility operating below the "small" size class categorization is able to remain unregistered and uncertified. Many farms process large amounts of animal wastes and agricultural byproducts (DSM Report, p.70). There are also compost piles shared by communities or multiple houses. For the purpose of this paper these uncertified locations were not included in the scope of this project but merit further investigation in future research. It is worth stating that our research showed that the risks and precautions relevant to informal sites of community composting are similar to those for residential or backyard composting.

Table 3. Certified Composting Facilities in the state of Vermont. Provided by the Vermont Agency of Natural Resources, Waste management and Prevention Division.

Certified Composting Facilities

Facility Name	Facility Town	Type	Feedstocks Accepted	Effective Date	Expiration Date	CertType	Status	Primary Contact	Primary Phone
Wise Worm Compost	Burke	Composting	CF, LY, MN, WG	7/17/2014	none	Registration (Small)	Operating	Nicole and Terrance LaPointe	(802)467-3954
Cookeville Compost	Corinth	Composting	CF, LY, MN, WG	6/26/2012	none	Registration (Small)	Operating	Robert Sandberg	(802)439-5563
Vermont Compost Company at Fairmont Farms	East Montpelier	Composting	CF, MN, OC	11/20/2013	12/31/2020	Categorical	Operating	Karl Hammer	(802) 223-6049
Clokey/Crawford Compost Facility	Fairfax	Composting	DA	8/3/2009	6/30/2014	Categorical	Operating	Jeffrey Clokey	(802)782-4833
Greater Upper Valley Solid Waste Management District	Hartford	Composting	CF, LY, MN, WG	2/13/2013	none	Registration (Small)	Not Operating	John Hurd	(802) 296-3688
Kingdom View Compost	Lyndon	Composting	CF, LY, MN, WG	6/10/2011	3/31/2016	Categorical	Operating	Eric Paris	(802)626-3265
Middlebury College	Middlebury	Composting	CF, LY, MN, WG	7/23/2014	none	Registration (Small)	Operating	Missy Beckwith	(802)443-5267
VT Natural Ag Products	Middlebury	Composting	CF, LY, MN, WG	2/25/2009	12/31/2018	Categorical	Operating	James H. Foster,	(802)388-1137
Grow Compost of Vermont	Moretown	Composting	CF, LY, MN, WG	3/4/2009	12/31/2013 currently under review	Categorical	Operating	Scott Baughman & Lisa Ransom	(802)793-8645
North Hollow Farm	Rochester	Composting	DA, WG, MN	12/18/2009	12/18/2014	Categorical	Operating	Myron Bowen	(802)767-4255
Hudak Farm	Swanton	Composting	CF, MN, LY, WG	2/9/2010	12/31/2014	Categorical	Operating	Richard Hudak	(802) 527-1147
Green Mountain Compost	Williston	Composting	CF, LY, MN, WG, CP	9/20/2010	6/30/2015	Full	Operating	Brian Wright	(802) 872-8100
TAM Compost Facility	Bennington	Composting	CF, LY, MN, WG, CP	1/29/2013	12/31/2017	Categorical (Medium)	Operating	Trevor Mance	(802)447-1300
Windham Solid Waste Management District	Brattleboro	Composting	CF, LY, MN, WG,	8/11/2012	none	Registration (Small)	Operating	Bob Spencer	(802) 257-0272
Dane Farm	West Charleston	Composting	CF, LY, MN, WG,	7/13/2012	none	Registration (Small)	Not Operating	Brian Dane	(802) 895-4006
Highfields Compost	Wolcott	Composting	CF, DA, LY, MN, WG, OC	7/7/2011	6/30/2016	Categorical	Not Operating	James McSweeney	(802) 472-5138

CF - foodwaste | CP - paper | MN - manure | OC - other
LY - leaf and yard | WG - wood waste | DA - animal offal or carcasses

Table 4. Certification requirements for composting in Vermont. Provided by the Vermont Agency of Natural Resources, Waste Management Division, 2012. Describes the size and output requirements for compost facility certification in the state of VT. Small, medium and large classes are subject to annual testing by the state and must submit reports of testing samples, however the exempt class must not.

SUMMARY OF COMPOST CERT REQUIREMENTS (based on 3/15/12 VTSWMR)

VERMONT
AGENCY OF NATURAL RESOURCES

4 LEVELS OF REGULATION			
EXEMPT[1]	SMALL (Registration Required)	MEDIUM (Cat Compost)	LARGE (Full Cert)
Composting < 100cy/yr any feedstocks	Compost management area must be <4 acres (does not include finished compost storage areas or leachate/stormwater mgmt. areas)	Compost management area must be <10 acres (does not include finished compost storage areas or leachate/stormwater mgmt. areas)	Compost management area >10acres, or do not qualify for medium (does not include finished compost storage areas or leachate/stormwater mgmt. areas)
Managing <3000 cy/yr leaf/yard/plant/wood & <20% is grass	Composting <5000 cy/yr feedstocks, Including not >2000 cy food residuals/food processing residuals. No animal mortalities, slaughterhouse waste, or offal.	Compost <40,000 cy/yr, Including not >5000cy/yr food residuals/food processing residuals. Including not>10 tons/month animal, offal, or butcher waste	Compost >40,000 cy/yr, or <40,000 total but >5000 cy/yr food residuals/food processing residuals, or >10 tons/month animal, offal, or butcher waste
Managing food residuals in a digester and <1% of design capacity is food	Compost <10,000 cy/yr of solely leaf, yard & untreated wood residuals	Or composting >10,000cy/yr of leaf & yard waste	
Composting only manure, bedding, & clean carbon bulking agent	Not eligible for "small" if exempt from Act 250 under 10 VSA §6001(3)(D)(vii)(VI) [The compost is produced on a farm primarily used for the cultivation or growing of food, fibre, horticultural, or orchard crops] Note exemption expires 7/1/14.	May require Act 250 approval	May require Act 250 approval
Composting vegetative farm waste on a farm from any farm			
Composting <1000 cy/yr food processing residuals on a farm		NOTE: Composting any amount of sewage sludge, domestic septage, or septage is regulated as diffuse disposal	
Composting animal mortalities & slaughterhouse waste from a farm on the farm			

[1] Note, there are also non-compost exemptions in the organics section (6-1103), including: 8) on-farm disposal of animal mortalities from the farm; 9) burying up to 4 animal carcasses/yr if siting criteria are met; 10) household pet burial on owner's property; 11) treatment or disposal of animals/birds/fish in case of emergency disease declaration; 12) Pet cemeteries.

After identifying these certified locations, we began conducting field studies and interviews with facility managers and employees at GROW Compost of Vermont, Vermont Natural Agricultural Products, Middlebury College's Compost Facility, and Windham Solid Waste Management. Through conversations and research on facilities we gathered information on composting techniques and ingredients used, sourcing of ingredients, quality control and contamination protocols, and distribution practices. We also obtained data on results from state mandated testing from Middlebury College's Compost Facility, Green Mountain Compost, Vermont Natural Ag Products, and GROW compost which offered information on contaminants like lead. These facilities are distributed throughout four counties in the state (Figure 1). In total we visited 3 composting facilities, and conducted 5 interviews, four in person and one over a telephone call (for interview questions see Appendix 2). Through this research we obtained a better understanding of the larger structure of composting practices, the flow of organic waste through Vermont, possible entry points for contamination, mitigation protocols for contamination, and the inflow and outflow of organic materials through these facilities.

Results

Household Responses

Our survey generated 99 responses and contact information for 47 participants. Our survey results provided us with insight into the general composition of compost in Vermont, preferred locations for compost bins, and the most popular uses for home compost. We found that out of 99 respondents, 43 respondents compost at home and use their compost in their garden and/or their yard. Of these 43 respondents, 100% of them incorporate yard debris in the form of leaves, grass clippings, weeds, and garden debris into their home compost. Figure 2 gives us an overview of how the respondents to our survey manage their yard debris. This figure provides insight into how at-risk Vermonters are of contaminating their compost with contaminated yard debris. Figure 3 displays the likelihood that possibly contaminated compost is placed over soil that people and children frequently interact with, possibly exposing these people and children to high lead concentrations.

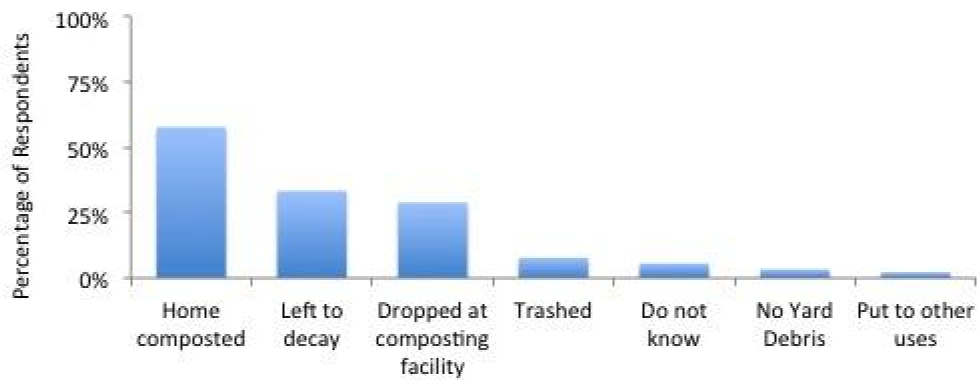

Figure 2: Management of Yard Debris. 90 of our 99 respondents answered the survey question regarding management of yard debris. Answer choices were not mutually exclusive.

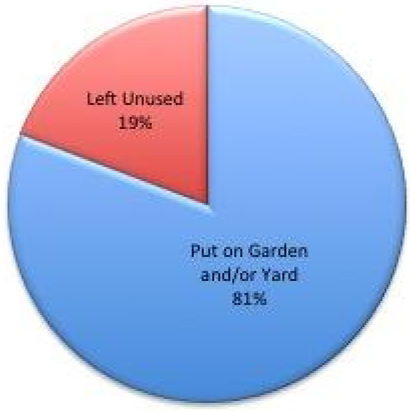

Figure 3: Use of Home Compost that Includes Yard Debris. Percentages are based off of a total of 52 respondents who include at least some of their yard debris in their home compost.

Household Compost Analysis

Our XRF analysis revealed that of the 32 samples that we tested for lead concentrations, samples from one location displayed lead concentrations above the Vermont standard of 300 ppm while samples from two other locations displayed lead concentrations above the EPA standard of 400 ppm (Figure 4). Students in CHEM0311 found no significant difference in lead concentrations determined by XRF and GFAAS, which indicates that XRF was equally as accurate as GFAAS for our application (Table 5).

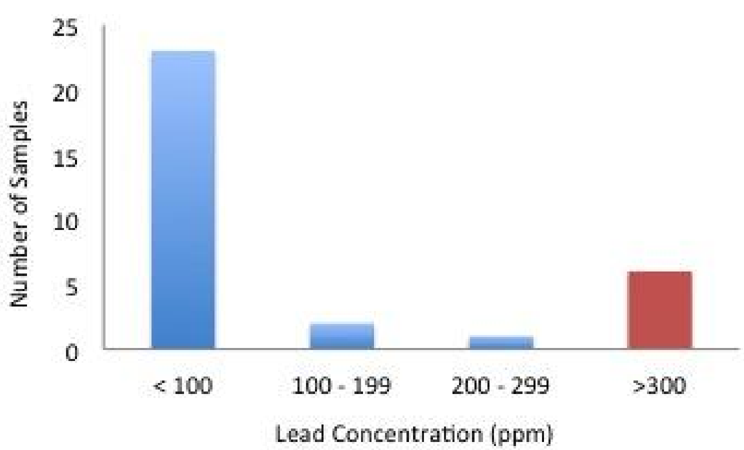

Figure 4: Lead Concentration Distribution of Household Compost Samples. Of the samples analyzed (n=32), 6 samples contained lead levels above the level deemed safe by the Vermont Agency of Natural Resources (>300pp). Concentrations were confirmed to be greater than 300 ppm by both XRF and GFAAS.

Table 5: XRF and GRAAS comparison. Compares the results from both the XRF and GFAAS analysis techniques. Sourced from the Middlebury CHEM0311 report (See 'Further Reading').

Sample ID	Pb by XRF (ppm)	Pb by GFAAS (ppm)	Sample ID	Pb by XRF (ppm)	Pb by GFAAS (ppm)
276 SU003	4094	4338	1_005	34	32
68MAB001	625	660	42BIR_S_0920	34	35
16CROW_001	499	397	CHIT_002	22	186
276SU_004	409	323	CHIT_001	20	na
68MAB_002	391	na[a]	2318RR_001	18	30
16CROW_002	353	289	2401RR_001	nd[b]	15
68MAB_003	259	212	TBPLAT40920	nd	21
SWIL_002	193	156	CPG001	nd	37
SWIL_001	190	106	RyanCompost	nd	22
62OLD_002	93	70	MCCOM1003	nd	28
62OLD_001	91	35	MCCOM1002	nd	25
DT_001	42	32	1_001	nd	35
MM_002	42	43	1_006	nd	27
DT_002	38	25	1923 NW 001	nd	5.6
CPG_002	38	18	1923 NW 002	nd	9.3

[a]na indicates no measurements were taken
[b]nd indicates lead was not detected

Facilities

Our conversations and research provided us with four different categories of information on composting practices at state-certified facilities: (i) compost techniques and ingredients, (ii) quality control and contamination protocols, and (iv) historical data on testing and contamination.

Composting Techniques

Compost should have a balanced ratio of carbon and nitrogen. This ratio should vary from between 25:1 to 30:1 (C:N). This ideal ratio ensures the quick and effective breakdown of organic matter by microorganisms and bacteria in the pile. The ratios are managed by composting facilities that create compost "recipes" in which they add different amounts of different ingredients. Some common ingredients are: wood chips, food waste, animal manure, leaf and yard debris, paper and sand. These components are mixed to ensure airflow, manage wetness and heat, and reach the correct ratio of carbon and nitrogen. At medium and large-scale facilities, batches of compost are processed to ensure homogeneity, and extensive mixing and turning of piles insures inputs are evenly distributed throughout an entire batch of compost.

Quality Control and Protocols

Facilities with full certification must submit quarterly reports to the Solid Waste Management division of Vermont Agency of Natural Resources (Stacy, 2009). Facilities with Categorical (Cat) certification are required to submit annual reports. These reports must include the types, amounts and source of solid waste inputs into their compost, and also include test results measuring parameters like pH, soluble salts, nutrient content, plastics, and trace metals.

In addition to complying with state regulated testing, most facilities also implement

ongoing testing by cultivating biotic samples in soil that has been enriched by their compost. This means that seeds or shoots are planted in the compost rich soil on an extended growth schedule. These plants are then intermittently assessed for signs of growth inhibition when compared to a control group of biotic samples planted in compost-free soil. If growth deficiencies are observed in these biotic samples, then the compost batch may be subjected to additional testing for contaminants. In this way, compost is monitored throughout the process of mixing and processing, not only as an end product. If compost is found to be contaminated, first the entire batch is disposed of in a landfill, or in a case where a private facility has access to ample open land the compost may be dumped at a location that is removed from human interactions. Additionally, if repeated contamination events occur, the facility will aim to track and eliminate the sources of this contaminant by tracing the inputs back to their suppliers. In the case that a contaminant source was identified, this ingredient supplier would be notified and their input removed from the cycle.

Historic Data

From our conversations with managers at regulated facilities, we gathered that no instances of significant lead contamination have been observed at these facilities. While the tests that are performed check for lead levels, lead as a contaminant was not highlighted as a high concern among facilities, nor did they recall instances when lead levels were found to be over the Vermont or EPA standards. In our conversations, concerns of compostable plastics, herbicides, and trash were highlighted as potentially problematic pollutants. Some examples of testing data are provided below (Figures 5,6). No instances of lead levels that exceed Vermont standards were identified in the data we obtained.

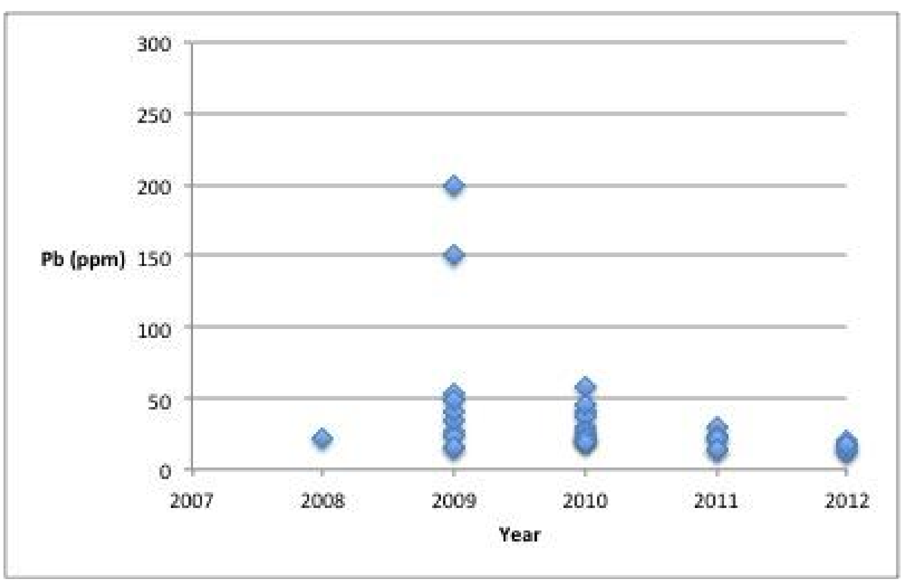

Figure 5: Historical data, Lead Composition for Green Mountain Compost. Samples collected between November 2008 and June 2012. n= 34 samples.

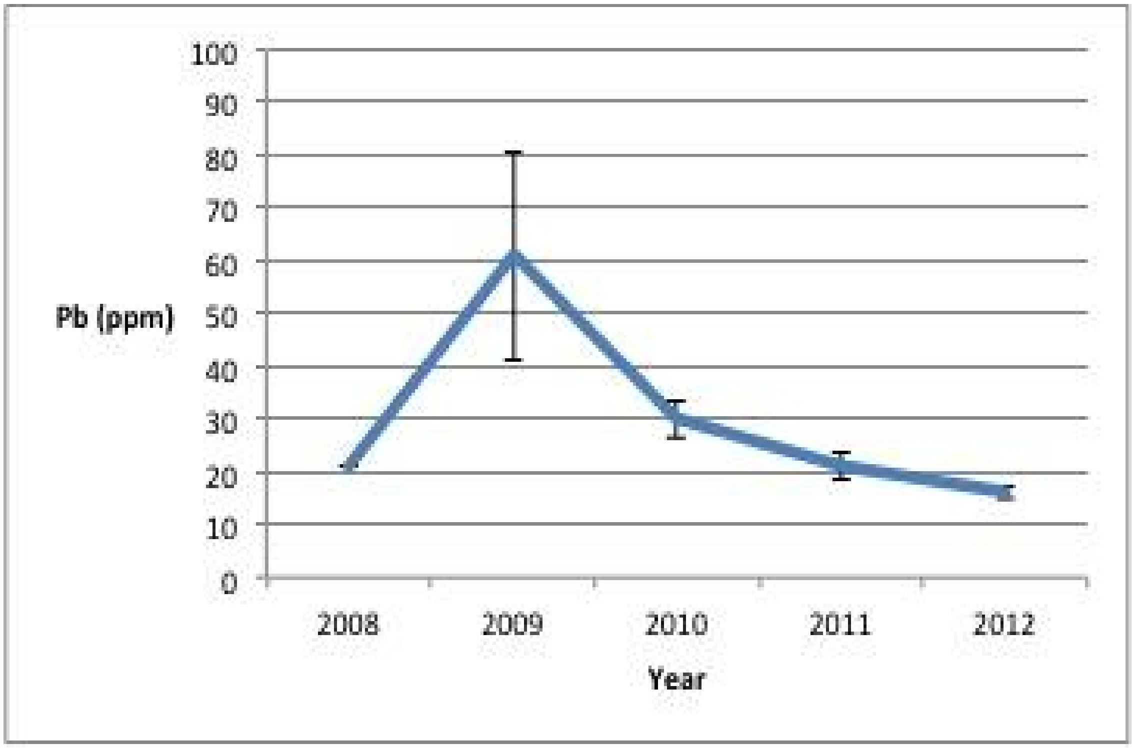

Figure 6: Historical data, Average Lead Composition in Green Mountain Compost. Samples collected between November 2008 and June 2012. n=32 samples.

Discussion

Households

Given that yard debris is one of the main pathways by which contaminated soil can mix with compost, we conducted our survey in order to gain insights into popular management practices of yard debris as well as whether or not people incorporate yard debris into their compost mix. As seen in Figure 2, over 50% of the 99 respondents compost at least some of their yard debris. This means that it is possible that the majority of Vermonters who compost are unknowingly contaminating their compost by mixing in yard debris from lead susceptible zones. Yard debris can contaminate compost by introducing lead contaminated soil into the compost mix.

Contaminated compost is the most dangerous when it is applied to gardens and yards due to the large level of interaction that children often have with the soil in their yards and gardens. Our results show us that 83% of people who incorporate yard debris into their compost use at least some of this compost in their gardens and/or yards. This means that the vast majority of people who include yard debris in their compost use their compost even though it could be contaminated. By using compost that includes yard debris, people may be putting themselves and their children at risk of exposure to high lead levels.

Because we only tested compost piles from survey-takers who willingly provided their address and contact information at the end of our compost inquiries, our sampling may represent

a group of people who are significantly more involved in composting practices than the average person. We would expect these composters to perhaps demonstrate more attention and care to their compost piles, as well as to utilize their compost more regularly. Therefore, we would expect that the average person in Vermont might interact with their yard debris and compost less than the respondents do in our survey. Hence, risk of exposure to lead via compost could be overestimated in our results.

Of our 32 samples we identified six samples from three locations in which lead levels were above the Vermont composting standard of 300 ppm (Figure 4). We concluded that these levels are accurate by using two different forms of analysis. While for the purpose of this study we will focus on these instances where lead levels violated Vermont standards, it is important to note that these standards have not only changed over the years, but are also not consistent across the US or around the world. For example, the EPA regulation for lead in soil is 400 ppm, while the Vermont ANR prohibits lead levels above 300 ppm in solid waste (Vermont Agency of Natural Resources, 2012). Furthermore, the EU standards for lead in compost and soil are only 150 ppm, much lower than in the US (Brinton, 2000). These inconsistencies in what lead levels are considered "safe" indicate a lack of knowledge and confidence in permissible amounts, and as a general rule lead levels should be managed to be as low as possible.

These sites with elevated lead levels demonstrated different characteristics of contaminated compost such as location, input, intended use, and contamination source. From these characteristics, key problems and solutions to reduce homeowner's exposures to contaminated compost were identified. These specific cases of compost contamination can be used as a broad framework for conceptualizing lead contamination problems in compost, and the specific concerns and practices are discussed below.

Case Study 1: Compost Spatially Removed From the House

(a) Site description: In this case, the sampled compost pile was located on the far edge of the back lawn approximately 20 ft. away from the house. The compost was a heterogeneous mix of food scraps and leaf and yard debris. Lead contamination in this context likely came from leaf and yard debris raked from around the yard contaminated with residuals of leaded gasoline on the side of the road or chipping paint from the house. The homeowners of this compost pile did not intended to use the compost on their garden or other close-to-home locations, but instead tended to leave the pile to decompose on site, removed from the immediate home environment.

(b) Site management recommendations: For this case of high lead in compost, the key to properly managing the contamination is to leave the compost pile untouched and spatially removed from the home environment. If the compost is not reintroduced into an environment where human contact could occur, but instead left to decompose in a removed location then the stabilization of lead in this pile is a good solution. The lead will become immobilized within the compost by binding with organic matter, and simply sit there unable to move into the surrounding environment. An important element to mitigation is education of the homeowners with this potential problem, informing them of the proper protocol for management. If homeowners are aware of this potential contamination through leaf and yard debris, or are able to test their compost for lead contamination they could capitalize on this form of lead stabilization and remediation. Allowing lead to remain stabilized in a spatially isolated compost pile is an effective plan for management as long as the pile is not reintroduced into a garden or yard environment. As a way to target the source of contamination homeowners should not include

yard debris in their compost that is gathered from near a road, or next to buildings that have visible peeling paint.

(c) Rationale for management strategy: Persistence and mobility are the main risks of lead exposure even in an environment that is removed from direct human contact. While some remediation tactics involve the removal of lead from a soil environment, other tactics simply focus on the immobilization and stabilization of lead in order to prevent this leaching and movement (Herwijnen et al., 2007, Hettiarachchi et al., 2001, Alpaslan and Yukselen, 2000). When exposed to certain substances, lead binds to other compounds during the process of complexation (Hewijnen et al., 2007). Through this binding process, lead becomes immobile and effectively stabilized in its current environment. While this process of stabilization does not remove lead from the environment, it does prevent lead from being taken up by plants, from leaching into nearby environments, and from freely moving around in soil or dust particles. Studies on lead stabilization have focused on the naturally occurring sources such as clays, compounds containing high amounts of phosphorus, and compounds like compost that contain organic matter (Herwijnen et al., 2007, Hettiarachchi et al., 2001, Alpaslan and Yukselen, 2000).

A study examining the use of compost as a lead stabilization technique confirmed that the addition of green waste compost—nitrogen rich materials such as kitchen food scraps—decreased the effect of lead leaching out of the soil, as well as decreased the bioaccumulation in plants and grass grown on that soil (Herwijnen et al., 2007). The researchers concluded that this was because of the formation of complexes between lead and the organic materials in the compost. By applying the conclusions of this study to the context of a compost pile that contains organic matter, we can conclude that compost is an effective stabilization medium for rendering a large proportion of lead particles immobile. If lead is introduced into this composting environment, it will become bound to compounds in that compost pile and will be unable to move to other environments.

For those that want to actively use their compost, we turn to our source management strategy. Studies have found that residuals from leaded gasoline typically contaminate roadside debris in decreasing levels as distance from a roadway increases (Pei, 2004). 99% of lead contamination from vehicle emissions is within 50m from the road. However Pei and Chaolin concluded that peak lead contamination is found within 5m of the road. This distance may vary according to traffic density and vehicle speed, however avoiding yard debris located 5m from the road is a good mitigation technique for most contexts. As for peeling paint from buildings, the zone within six feet of the home is called the "drip zone," and the EPA classified this zone as containing the highest levels of lead from peeling paint (Black and Veatch Special Projects Corporation, 2007) . While in theory paint chips could spread outside of this zone, this is the highest zone of contamination and concern, thus debris from within six feet of the home should not be included in compost. By not including yard debris that has come from within these two zones, home composters can limit this source of contamination into their compost.

Case Study 2: Compost Close to the House

(a) Site description: In this case the compost pile was located approximately five feet away from the house, next to an old shed with visible peeling paint. The compost was mostly comprised of household food scraps and organic waste. Lead contamination in this context likely came from lead paint chips and dust from the adjacent peeling shed. This compost pile was used for soil amendment and was periodically spread on the home garden. The homeowners were aware of the possibility of lead contamination on their property, and had planted sunflowers

between the painted shed and a nearby garden plot as a means of remediation.

(b) Site management recommendations: For this case of lead contamination in compost that is close to the home environment, the key to limiting health risks is to decrease bioaccessibility and bioavailability. Phytoremediation as a strategy to limit bioaccessibility is inexpensive, and without the use of chelates, it is a natural remedy with little or no impact on the environment. One critique of phytoremediation is that it takes several plant rotations to adequately remediate Pb contamination, therefore, the decision to use phytoremediation as a tool to address Pb contamination should be considered on a case-by-case basis. In order for this strategy to target compost specifically, phytoremediating plants would have to be grown directly in the compost to remove lead contaminants, then safely disposed of in a landfill, or taken to an authorized waste management facility for incineration before disposal.

Additionally, the natural occurrence of phosphorus in compost effectively limits lead bioavailability. If lead is present in a compost pile, the binding properties of phosphorus may render the lead contaminants less bioavailable, and thus even if accidental exposure or ingestion of compost particles occurs, the absorption into biological systems may be limited. This aspect of bioavailability encourages the inclusion of household food scraps in compost piles as a potential source of phosphorus. Finally, as a way to target the source contamination in this context, homeowners should compost in a closed container to limit contamination from peeling paint.

(c) Rationale for management strategy: In an environment with high lead levels and the potential for human contact, the issue of exposure lies within the concepts of bioavailability and bioaccessibility. Limiting the bioaccessibility and bioavailability of lead to humans can be approached in two ways. First, plants can be used to remove lead contaminants from soil, a process known as phytoremediation (Hughes et al., 1997). By concentrating lead within plant structures, although the contaminant is still present in the immediate environment its bioaccessibility to humans is decreased. Lead contaminants are not available to human circulatory systems if they are stabilized within the roots and stems of plants and flowers. Plants that absorbed the contaminants can eventually be harvested and removed from the soil, ultimately removing lead from the surrounding environment if they are disposed of properly.

The disposal of these plants is an important aspect in ensuring the contaminants don’t get reintroduced into the environment. A common practice is for the plants to be incinerated in a Pb/Zn smelter or incineration plant so as to prevent Pb from entering the environment (Nowosielska et. al, 2004). The burning of the plants will isolate the Pb from organic matter and emit the Pb as dust to be captured by flue gas-cleaners (Nowosielska et. al, 2004). The incineration process creates ashes that are less than 10% in volume than the original pre-incinerated matter, which will then be collected and disposed into a landfill (UNEP). This treatment occurs at the facility level due to limited studies on disposal tactics at the homeowner level, and therefore it is important to provide information to homeowners about how to isolate their contaminated matter from the environment.

Not all plants are capable of effectively absorbing Pb contaminants (Table 6). Researchers have found that Indian mustard (*B. juncea)* is the most effective plant for extracting contaminants from soil (Satpathy & Reddy, 2013). The table below from Kumar et al. (1995) shows the levels of lead absorbed across a number of plants.

Table 6: Absorbed Lead Content of Roots and Shoots of Crop Brassicas and Other Plants (Kumar et al. 1995). Plants were grown for 14 – 20 days in a substrate containing 625 μg of Pb^{2+}/g DW supplied as Pb(NO--$_3$)$_2$ (n = 4).

Plant species	Mg of Pb/g dry weight ± SE (over a 2-3 week period)	Mg of Pb/g dry weight ± SE (over a 2-3 week period)
	Shoot	Root
Indian mustard/Chinese mustard	10.3±2.9	103.5±12.3
Black mustard	9.4±2.5	106.6±10.7
Napa Cabbage	7.2±2.2	103.4±7.7
Abashow Gomen (Amragna)	4.6±2.6	108.9±13.9
Rapeseed	3.4±1.0	61.2±11.9
Cabbage	0.6±0.2	52.7±3.8
Sunflower	5.6±1.3	61.6±3.3
Cultivated Tobacco	0.8±0.3	24.9±7.8
Sorghum	0.3±0.0	8.2±0.6
Smooth Amaranth	0.3±0.04	8.7±0.7
Amaranthus paniculata L.	0.4±0.04	8.9±0.3
Corn	0.2±0.1	14.7±0.9

Lowering the pH of soil is a beneficial additional step to take under phytoremediation. A lower pH increases lead mobility in soil, which makes it easier for phytoremediation to occur (Doyle, 1998). The lower pH can be achieved by adding organic materials like sulfur, coffee grounds, or pine needles (Earth Repair, 2013). Alternatively, the introduction of synthetic and biodegradable chelates into the soil also increases Pb uptake in plants. Synthetic chelates include Ethylenediaminetertraacetic acid (EDTA) while biodegradable chelates include ethylenediaminodisucinate (EDDS) and nitrilotriacetic acid (NTA). However, these synthetic chelates do increase the potential for leaching and pose a risk for groundwater contamination, thus they should be used sparingly (Zhao, 2013).

A different approach to the issue of bioavailability was explored by Hettiarachchi et al. (2001). In this instance, instead of limiting lead exposure pathways researchers attempted to find a way to limit lead absorption into the human body even in the case of direct exposure. This study attempted to model the environment of the human stomach, creating specific acidity and other factors that would influence bioavailability and the mobilization of lead into biological fluids. They found that when phosphorus was introduced to the lead rich environment, the

bioavailability of lead within the modeled human stomach was decreased.

This finding indicated that the health risks of human exposure to lead are not only dependent on the extent or scope of exposure, but also the chemical properties of the lead and how available that lead is for uptake into the human body. If phosphorus is able to bind to lead prior to human exposure, it is rendered less toxic and is less readily absorbed into biological systems. The decreased toxicity is likely due to the alteration in the mobility of lead. Phosphorus is a mineral that is found in natural forms such as bone and rock. Foods that are high in protein also contain high levels of phosphorus, for example nuts, grains, meat, poultry and banana peels. While meat and poultry are typically not recommended for inclusion in compost piles (due to potentially unpleasant odors and the attractions of pests), most compost piles that include household food scraps will exhibit high enough levels of phosphorus.

Education and Awareness

Most homeowners in Vermont are unaware of lead contamination around their home environment and are also unaware of remediation strategies to reduce their exposure. This lack of awareness is perhaps due to the covert contamination pathways for lead in compost, and the fact that it can accumulate from many sources like air, soil, water and paint (Karami et al., 2011). Lead's presence around the home environment could put families at risk. The gap in knowledge of lead contamination in compost and remediation strategies prevents homeowners from being equipped to protect themselves against lead. Therefore, education and awareness of contaminated compost and strategies to reduce exposure to it are critical aspects of protecting the health of homeowners in Vermont.

If homeowners are made aware that compost is a potential pathway for lead contamination and increased health risks, they can subsequently take steps to mediate this exposure through the tactics outlined in Case Studies 1 and 2. This education can occur through information distribution through gardening facilities, community outreach programs, and through agencies like the Vermont Department of Health. An example of our outreach material is reproduced below (Figure 7).

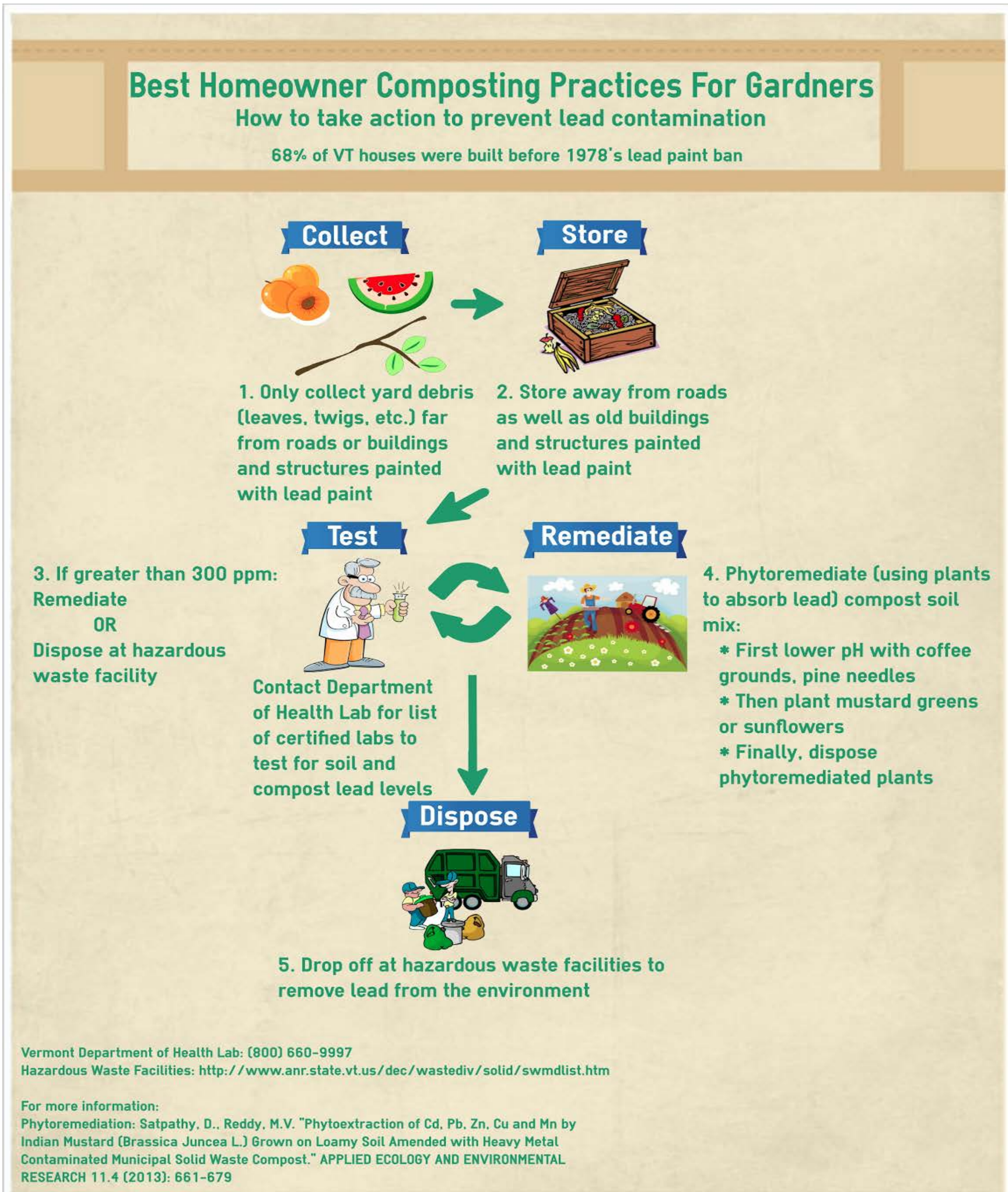

Figure 7: Best Homeowner Composting Practices for Gardeners: How to Take Action to Prevent Lead Contamination.

Alternatively, if homeowners are uninterested or unwilling to become educated about safe composting practices, allowing certified facilities to safely process their compost is a good alternative strategy. Upcoming legislation and infrastructure that will encourage the disposal of compost at certified processing facilities is further examined below. In this analysis we raise potential issues with this legislation, as well as highlight benefits to the widespread adoption of this system.

Facilities

Our results from conversations, research, and analysis of obtained data provided us some important insights into the issue of lead as a contaminant in composting facilities. First, our examination of the makeup of compost, ingredients and processing that takes place indicates that even if lead does end up in a large scale composting system, it is most likely diluted amongst many other components of compost and distributed through an entire batch in trace amounts. The lead levels that are observed in compost testing data provided above support this. Two samples from Green Mountain Compost in 2009 reported levels that were higher than normal, although these were still in compliance with state standards (Figure 6). Because lead levels subsequently decreased in following tests, this could have been due to a contaminated input that the facility stopped including in their compost.

Second, all facilities appear to have in place effective means of monitoring compost quality, testing for the presence of contaminants, and mitigating these contaminants should a problem arise. If high levels of lead were found in a batch of compost, then that batch would be disposed of, the source identified and eliminated as an organics source. Third, by examining the historical and current data on lead contamination, it seems that this problem has never been witnessed in the past. Theoretically lead contamination on a large enough scale to pose a threat to a composting facility would have to come from leaf and yard debris, as witnessed in the case of Boston in 2012. When this case was mentioned however to composters in Vermont, they surmised that perhaps if they were literally only composting lead laden yard debris that this could pose a threat, but as it were this is simply not the case and their ingredients come from a variety of sources, leaf and yard debris only making up a small proportion of overall composition. Together, our myriad observations demonstrate that the issue of lead contamination in composting facilities is not a concern for Vermont.

Conclusion

The Vermont Agency of Natural Resources set the safe standard of lead contamination in compost at 300 ppm. It is important to note that while compost can be a remediation tactic for lead contamination in soil, it may still be contaminated for reasons such as its proximity to buildings with old paint and the abundance of yard litter with lead dust in the compost. We have identified several best practices for composters to follow to prevent high levels of lead contamination in compost.

Our lab analyses on lead levels in compost revealed the potential for lead contamination to occur in the compost of homeowners. We believed that it would be necessary to engage homeowners around their composting practices because they could be directly affected. Therefore we decided to develop a poster to be distributed to homeowners, specifically gardeners, to share best composting practices for safeguarding against lead contamination in compost on the residential scale.

Highlighting best composting practices in our poster is suitable and important information to provide to homeowners. This is because homeowners are not subjected by law to test their composts. Therefore they may be unaware of the contaminants that can be found in compost and the effects on human and environmental health. These best practices outline preventative measures that homeowners can follow to reduce their exposure to lead. If homeowners do recognize that they have high lead levels around their home, these best practices are extremely valuable remediation tactics. Dropping off compost at a composting facility or hazardous waste facility is not a remediation tactic currently available to homeowners.

The culture surrounding Vermont composting is strong, spanning the many demographics and geographies of the State. As a practice, composting continues to grow in popularity as people become better educated about its multitudinous benefits and understand its importance as an emblem of sustainability in Vermont. As such, it is paramount that composters are informed and able to respond to the potential threat of persistent toxics like lead. As composting outreach groups like the Composting Association of Vermont continue to expand their target audience, and composting techniques are continually refined, so too are the State policies surrounding the disposal and reuse of organic matter. The Vermont Universal Recycling and Composting Law, or Act 148, is the political manifestation of the State's composting culture, and currently the focus of many composting stakeholders, most specifically compost facility managers. The sudden increase in quantity of organic matter that is expected to hit large scale composting facilities over the next five years has made many Solid Waste Management Entities nervous about quality control of the incoming organics. Due to this concern, Part II of this report delves into an analysis of the implementation of Act 148 and what significant changes Vermont residents, businesses, and organizations can expect to see in the ensuing years.

PART II: Expectations for the Implementation of Act 148

Introduction

As global climate change moves closer to the forefront of national & state priorities, innovative ways to reduce CO_2 emissions in Vermont will be incorporated into the State Climate Change Action Plan. One GHG reduction tactic that will continue to take precedent is the reduction of methane (CH_4) emissions, a large percentage of which come from the anaerobic decomposition of organic matter in landfills. In recognizing the advantages of encouraging sound composting practices both on the residential scale and larger facility scale, Vermont put forward the ambitious Universal Recycling Bill outlining an explicit path towards achieving 100% diversion of organic waste from landfills. This Bill was unanimously passed into Law in July 2012, and the first benchmark of implementation has already begun as of summer 2014.

The Agency of Natural Resources (ANR), which is the governmental body responsible for the implementation of Act 148, is in the midst of a full-on media campaign to make sure people understand the upcoming requirements for businesses and residents under Act 148. In addition to the public outreach they are doing, ANR is making a concerted effort to identify and ameliorate any unexpected issues that weren't foreseen by the lawmakers. From our research and discussions with ANR members and people affected by this law, we found that a thorough dissemination of Act 148 information will be integral to realizing the universal recycling goals in a cost-effective manner. Almost all of the anticipated problems of implementation can be traced back to the disposal choices of individuals, thus necessitating a comprehensive refinement of cultural norms related to disposal decisions, and sustainability more broadly.

Many Vermont residents are disconnected from waste disposal processes. For your average resident, waste stream knowledge stops at the curbside, where waste hauling companies are paid to transport and dispose of trash. With the important role played by residents, both ANR and Solid Waste Management Entities (SWME)—the district level waste managers in Vermont—have recognized the importance of delivering dynamic educational materials to Vermont residents through the most effective means possible. While the presence of outreach in schools and community centers is integral to promulgating Act 148 objectives, we identified what we see as another very effective medium through which to enforce/incentivize good recycling and (more relevantly) composting behavior: waste hauling. It is instrumental that private hauling companies, which collect 79% of residential and commercial waste and recycling, are well prepared for the changes that will stem from this law so that they can properly connect with their clients to inform them of changes in policies (DSM Report, 2014). Act 148 is going to have the largest effect on private haulers. For this reason, the rest of our policy analysis will focus on the private hauling sector, which is made up of small, medium, and large-scale haulers.

Under the new legislation, small haulers must offer organics curbside pick-up services, which means they must be able to accommodate three types of waste: landfill trash; (single-stream) recycling waste; and organic waste. As stated on the ANR Act 148 homepage, "All haulers who provide trash collection will eventually be required to offer collection of recyclables, leaf and yard debris, and food scraps, or to sub-contract with another hauler to provide these services to their customers." The high cost of retrofitting hauling trucks means that the policy inherently (albeit unintentionally) selects for large-scale hauling companies, potentially putting small-scale haulers out of business. As an ever-changing, flexible policy, an amendment that was passed this summer got rid of a waste-segregation exemption for haulers moving under 1 ton of waste a week. While this closed an exploitable loophole in Act 148, it was

not replaced by any proposal that would help subsidize the anticipated costs of the Law. One can argue that Vermont culture—and many of the policies that provide a legal structure for that culture (e.g. Act 148)—is based on ideals of localization. Local consumption & disposal fit snugly into that ethos, as do local businesses. High retrofit costs have the potential to become disincentives for the development of local, specialized organics collection businesses, thereby increasing the reliance on larger haulers who can manage retrofit costs more easily.

"The convenience of access to organics management facilities can significantly influence participation rates" (ANR MMP, p.33). The rural nature of the Vermont population necessitates the existence of small hauler companies that can offer services to specific regions. By looking at the influence and political agency of small-scale businesses we can also assume that regionally specific haulers have a greater capacity for interpersonal relationships and instilling appropriate composting behaviors.

For reasons that this paper will continue to elucidate, we propose a cost subsidization for the retrofit or full replacement of the hauling vehicles owned by small and medium sized haulers. This subsidization could keep many small haulers in business and therefore help strengthen the infrastructure needed to implement this Law. Implementing Act 148 will be expensive in other ways as well, necessitating the generation of additional capital. This paper recommends a number of additional sources of funding that should be explored in more depth by groups like the ANR Waste Division or the Solid Waste Infrastructure Advisory Committee which was set up by Act 175 and consists of individuals from ANR, private hauling groups, SWMEs, and the like. Lastly, one of the highest priorities over the next few years of this Law's implementation is ensuring high levels of compliance. Without explicit financial penalties for non-compliance, it is highly unlikely that this law will realize the highest possible levels of compliance. This policy review therefore outlines a structure of non-compliance fines that should be enforced by ANR on SWMEs. With the correct structure, these fines will trickle down to the residents who will be required (through fiscal penalties) to comply with waste separation guidelines.

Legislative History & Act 148 Background

Act 148

Vermont is the first state in the nation to implement a comprehensive ban on all recyclable and organic materials from entering the landfill. Passed unanimously by the Vermont legislature in 2012, Act 148 seeks to redirect all recoverable resources in the state's waste stream away from landfills by 2020. The compostable resources currently make up 28% of the material that is deposited into landfills across Vermont and its adjacent states (State of Vermont Waste Composition Study 2013) (Figure 8). In 2009 alone, 58,000 tons of recyclables ended up in the Casella Waste Systems Landfill in Coventry, Vermont, representing an estimated value-loss of $7.5 million dollars (CSWD, 2011). Using a composition analysis of Vermont residential Municipal Solid Waste (MSW), and a conservative value estimation of marketable compost, we came to the rough estimation that $3.05 million of those dollars would come just from diverting organic waste towards composting facilities. In addition to that forgone revenue, each ton of organic waste that ends up in a landfill generates an average of 2.8 metric tons of CO_2, 2.5 metric tons of CH_4, and trace amounts of non-methane organic compounds (NMOCs) (California Air Resources Board, 2013).

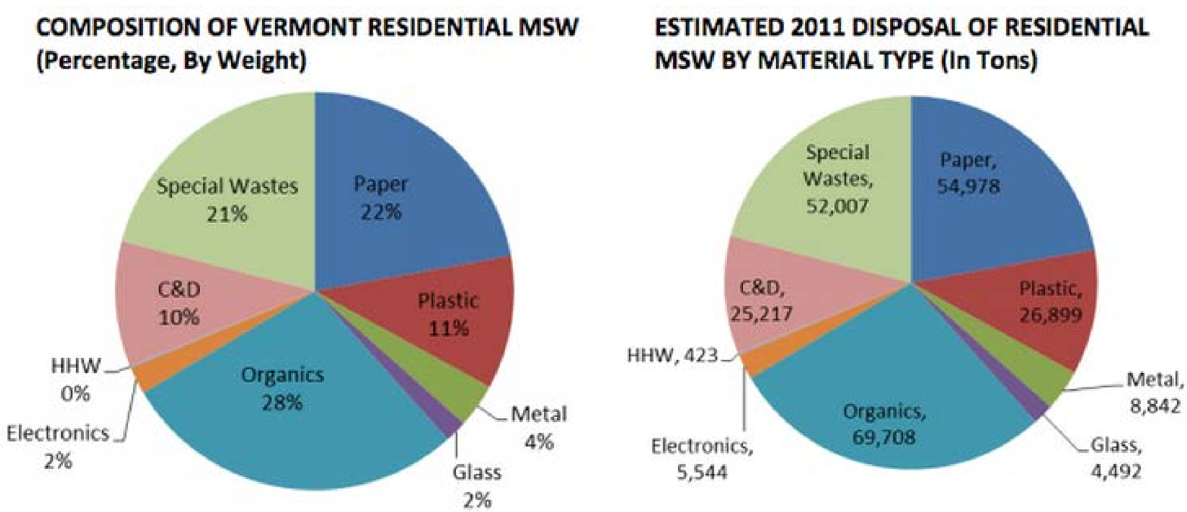

Figure 8: The composition of Vermont residential municipal solid waste. Broken down into Paper, Plastics, Metal, Glass, Organics, Electronics, Household Hazardous Waste (HHW), Construction & Demolition (C&D), and Special Wastes (any potentially infectious medical waste (PIMW), hazardous waste, pollution control waste, liquid toxic waste, and small scale industrial process waste. (Vermont Agency of Natural Resources, 2013).

Removing just 50% of the divertible material from the Vermont waste stream would prevent over 80,000 metric tons of CO_2 from entering the atmosphere each year (USEPA, 2010; CSWD, 2011). Additionally, Vermont is left with one operating large-scale landfill after the shutdown of the Moretown landfill in March of 2013, which is rapidly filling up. The primary impetus for the creation of Act 148 was thus, 1) to recover valuable materials that would otherwise be lost to burial, 2) to reduce harmful greenhouse gas emissions, and 3) to minimize the load in an already congested State landfill system.

In an effort to completely close the loop of organic waste recycling, Act 148 puts particular emphasis on Environmentally Preferred Purchasing (EPP) by government entities (Act 148: 1. 10 V.S.A. § 6602). The benefits to this closed-loop system range from decreased reliance on fertilizer to stimulation of local composting markets. ANR has also developed online resources that exist to help citizens locate the most convenient composting locations and establish habits that will allow for effective implementation of the Act 148 legislation (Appendix 3).

Act 250 & 78

Act 148 interacts with the existing legislation upon which it was built. Act 250 (also known as Vermont's Land Use and Development Act) followed the opening of interstate 89 and additions to I-91 in the 1960s. These highways brought a new wave of development and Act 250 mandates that the ANR review the potential impacts that development projects have on air, water, wildlife, and *waste*. In outlining proper management of waste from new development, Act 250 also established a precedent for waste management in the state that governs the establishment of new waste disposal facilities and composting facilities (ANR, "Act 250"). The second Act related directly to Act 148, Act 78, passed in 1987 as Vermont's first solid waste management law. This legislation led to the establishment of 16 Solid Waste Management Entities (SWME), which manage the waste flow of the towns within each district's jurisdiction (Figure 9). Act 78 prompted public regulation of not only waste, but also recyclables, compost,

and hazardous materials. It also established the framework within which ANR has begun to implement Act 148 as of December 2014 (Vermont State Legislature, “Act 78”).

This framework has proved to be more constrictive than helpful with regards to the role out of Act 148. The legacy of Act 78 (and Act 250) slows down the processing of permits, which are necessary for the development of additional waste management infrastructure. Figure 9 emphasizes the difficulties of making any statewide change to the waste stream by visualizing the somewhat haphazard organization of the SWMEs across the state. This figure also shows that many towns opt out of management by State run SWMEs to develop their own waste management plans, and that the size and organization of SWMEs vary significantly. SWMEs develop their own Solid Waste Management Plans, which control the treatment of residential waste, hazardous waste, recyclables, etc. To treat each material appropriately, SWMEs combine public and private resources (e.g. municipal compost facilities, private hauling companies and state administrators) to handle each type of waste. For example, in 2010 Addison County utilized a district-mandated ordinance that required all businesses and residents to separate recyclables from waste. It also means that some districts rely more heavily on private haulers for curbside pickup or a private composting facility for organics processing. In implementing Act 148, ANR must navigate the complexity of SWMEs throughout different stages of enforcement, compliance, education, and funding.

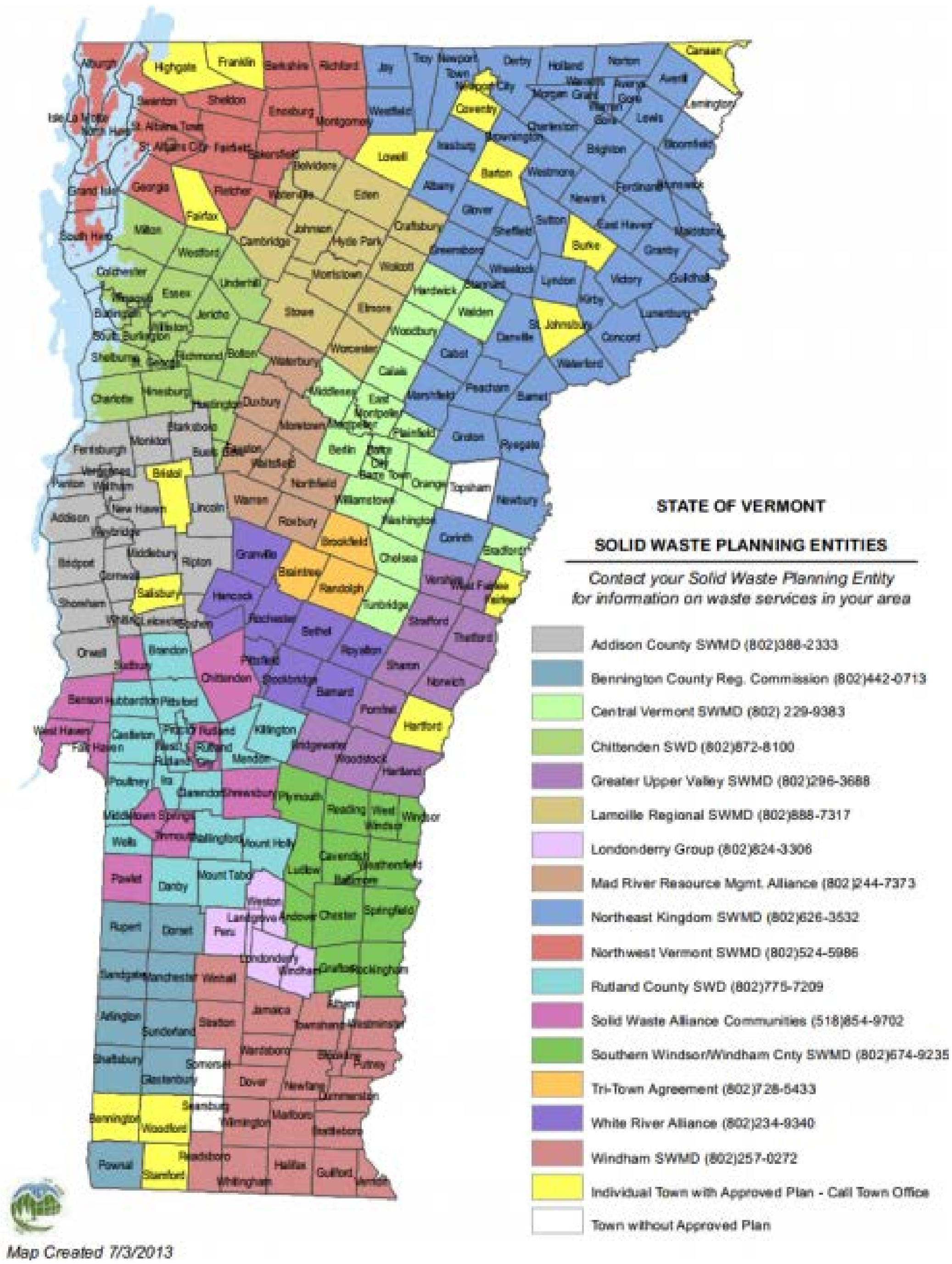

Figure 9: The Agency of Natural Resources map showing town membership in Solid Waste Management Entities (DSM 2014, p. 70).

Act 148

Overview

Act 148 targets those that contribute most to the waste stream first. This year, those businesses that produce more than 2 tons a week of organic material must divert these materials

to composting facilities. As we approach 2020, more stringent bans go into place and progressively smaller waste producers must come within compliance of the law, ending with the diversions of residential organics in 2020. Figure 10 provides a timeline for the aforementioned implementation of the law.

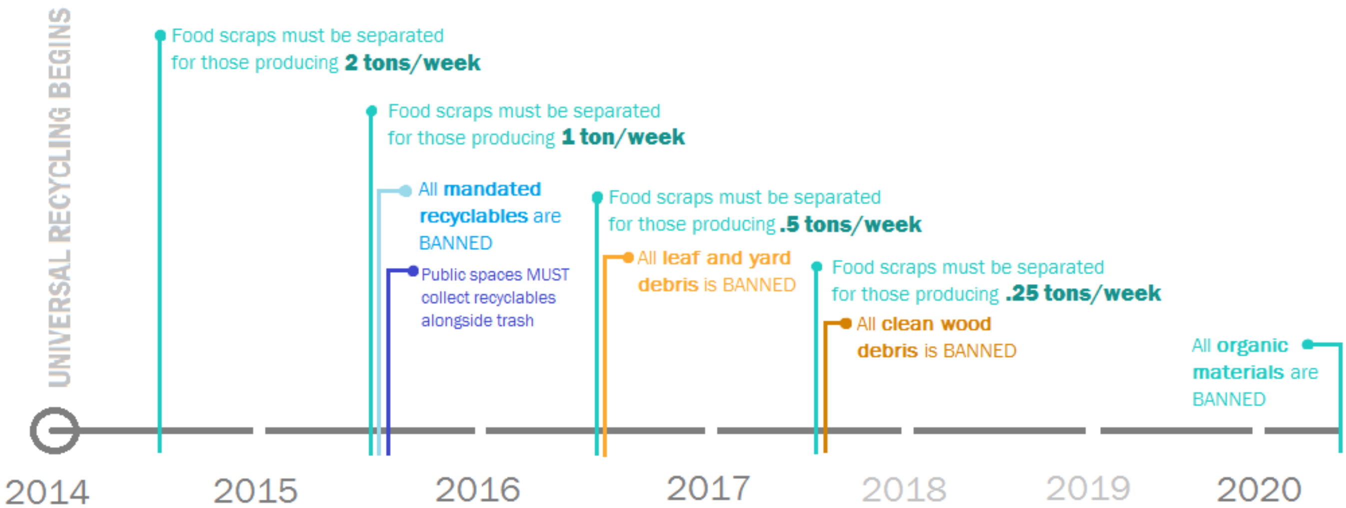

Figure 10: A cohesive implementation timeline outlining the affected stakeholders over the time period of the Act 148 implementation. As demonstrated by the final note on the right side of the graph, *all organic materials* are banned from landfills by 2020 under Vermont State Law (Flagg, 2014).

Sub-section 6605k of Act 148 specifically addresses the organic waste stream in Vermont. This subsection of the legislation uses a clear prioritization of goals for the diversion of organic waste from landfills. More specifically, it follows the stream of organic waste from source to facility, and through its list of priorities emphasizes the importance of community buy-in and a cultural shift that would reduce the amount of waste that is sent to landfills in the first place. According to Act 148, it is up to the Vermont ANR to make sure that the implementation of the Universal Recycling and Composting Law takes into account the following hierarchy of goals:

1) Reduction in the amount generated at the source
2) Diversion for food consumption by humans
3) Diversion for agricultural use, including consumption by animals
4) Composting, land application and digestion
5) Energy recovery

Coalition Building Under Act 148

Establishing a Precedent

Vermont has always pushed the envelope on issues of environmental concern. This characteristic is what attracts many people to Vermont: a lively, ambitious, environmentally auspicious political climate. Although San Francisco, Portland, and Seattle have all recently adopted “organics diversion programs,” and Massachusetts has set the groundwork for a ban on Industrial-Commercial-Institutional organic waste at disposal facilities, Act 148 places Vermont in the political and environmental vanguard (DSM Report, p. 56).

In Vermont legislature, “*organics*” are defined as, “materials derived from living

organisms such as leaf and yard debris, food scraps, clean wood, and paper and paperboard products" (Source: MMP, p.30). In the U.S., even after recycling and composting diversion programs are considered, almost half of the material sitting in municipal landfills is comprised of organic waste (US EPA, 2009). In comparison to this national statistic, roughly 28% of the trash that ends up in Vermont landfills is organic material that could otherwise have been composted (The State of Vermont Waste Composition Study, 2013).

The benefits of composting, such as CH_4 reduction, the conservation of natural fertilizer, and benefits to anaerobic digesters, have long been known and embraced by Vermonters. For many, Act 148 is a redundancy that will do nothing more than label an old habit as "*in compliance*" with State Law. However, for certain Vermonters, this law will mean the assumption of new habits and new values, which cannot be formed without widespread support. Therefore, with the enactment of Act 148 comes the urgent need to strengthen and support the existing composting culture. Because the success of Act 148 depends on every Vermont citizen, the only way to uphold this legislative precedent is by fostering a cultural precedent through outreach.

Outreach & Education

Senator Ginny Lyons, one of the authors of the Bill, calls effective outreach and education "critical to the success of the Law" (Lyons, Personal Comm., 11/21/14). Knowing this, the Vermont Agency of Natural Resources and their advisors are in the midst of a full-on media campaign to ensure people understand the upcoming requirements for businesses and residents under Act 148. Yet Lyons goes on to explain how ANR's outreach campaign—as impressive as it is—will have to be extended through a wave of outreach allies, which she identifies as schools, universities, community organizations, and enterprising coalitions of volunteers.

In addition to having its own education and outreach responsibilities (notably the duty of making sure all state employees are well-versed in organics management) one of ANR's main responsibilities consists of organizing and delegating outreach goals to other Vermont entities, such as the Food Cycle Coalition and the Farm to Plate Nutrient Management Task Force (MMP, p. 33). According to the SWMEs, private composting facilities, and Vermont residents we interviewed, support for this law's cohesive implementation is ubiquitous across both private and nonprofit sectors, which comes as no surprise given the legislative unanimity of the Law. However, translating interest into action requires additional, well-conceived steps.

As a great example of reduction in unnecessary waste, ANR has formed a strong partnership with the Vermont Food Bank, in an effort to prevent edible food from being wasted as a nutrient source. In an effort to reduce waste at its true source, production, ANR is also very aware of the importance of ensuring responsible end-of-life waste management, although this gets tricky in the discussion of organic waste. Ideally, Vermont will see a major increase in at-home composting rates, which is one of the foundational goals underlying Act 148. We can also expect Vermont entrepreneurial spirit to make local food composting easier than curbside pickup, resulting in more home gardens, healthier eating habits and a better understanding of plant growth cycles and effective land management.

Grassroots Organizing

Only through the mix of new businesses, non-profit coalitions, and impassioned citizens holding one another accountable can the State achieve compliance on an "All Organics Ban" by 2020. It will take an especially concerted effort to establish good composting practices among

demographics where composting values are less salient, namely, amongst senior citizens (Lyons, Personal Comm., 11/21). The creation of a summer 2015, "*get the word out*" core volunteer program directed at the Vermont demographics that are expected to have low compliance rates has the potential to propel the State towards Act 148 goals. Drawing on the youth passion for environmental causes, this program would consist of student volunteers, whose efforts would also generate cross-generational alliances and collaboration. We see this type of program as an effective way to prevent the improper disposal of organics at the source, and believe that there is enough to be gained from this that ANR should support a *"get the word out"* outreach program and consider it a pillar of their education efforts in implementation of Act 148. This campaign could involve collaboration with or supervision from Vermont Public Interest Research Group (VPIRG) across different Vermont counties.

Ensuring Compliance

The community buy-in created by the outreach efforts done by ANR and its advisors will play a large role in ensuring compliance. However the mobilization of community organizations and strengthening of cultural norms can only go so far. There will always be individuals (and even entire businesses) who will test the boundaries of the law in order to save money or for convenience. One of the largest gaps left open by the Universal Recycling and Composting Law is how to enforce compliance with this mandatory regulation. As the organization responsible for turning policy into action, ANR is responsible for municipal-level rulemaking, which includes enforcement of the law. And yet, according to Robert Spencer of Windham Solid Waste District, "even as we rapidly approach the first compliance benchmark [July 2015] the Agency of Natural Resources is unclear as to how they plan on enforcing compliance with Act 148" (Spencer, Personal Comm., 11/17/14).

As it stands now, enforcement shall be complaint-based. In other words, employees at waste management facilities/transfer stations will report improper disposal and penalize the perpetrator. At this point in time, ANR has not defined the nature of these penalties or who would assume the burden of the fine. In a Spring *Biocycle* article, Spencer goes into deeper detail on the issues of compliance:

> "*Although PAYT [pay as you throw] is the primary mechanism for promoting compliance with Act 148, ANR is also publicizing that... there will be enforcement actions, particularly based on complaints about noncompliance. ANR emphasizes that it will rely primarily on education and outreach to achieve the law's goals*" (Spencer, BioCylce p. 4).

Although ANR is the organization ultimately held responsible for enforcement, they are passing part of the enforcement responsibility to solid waste districts who they believe have enough authority to effectively enforce the law, at least initially (Spencer, BioCycle, p. 3). From regulation of SWMEs, private haulers will then be expected to enforce mandatory separation of organics. However, as stated in the DSM Report, this is an unreasonable assumption because it would cause private haulers to run the risk of losing customers to other hauling companies with more lenient enforcement of the Law (DSM Report, 2014). Only when there is a "level playing field of financial enforcement regulations" in the form of transfer-load and disposal-load inspections by ANR, will haulers have enough incentive to invest in methods to enforce the mandatory separation of organics (DSM Report, 2014).

One explanation for the flexibility in ANR's enforcement methods is the argument that SWMEs have the ability to set more stringent regulations than state-level officials (e.g. Addison County ordinance mandating recyclables be removed from waste as mentioned above). SWMEs are capable of enforcing their own ordinances and are poised to be able to assist in the implementation of Act 148. In fact, ANR is also relying on SWMEs to help with outreach in the towns they manage. The dissemination of information in schools and within waste hauling departments has been carried out primarily by SWMEs thus far (Lyons, Personal Comm., 11/21/14; Spencer, Personal Comm., 11/17/14).

SWMEs will create financial penalties for dumping "adulterated" waste, which could create varying fines from town to town, but currently penalties do not exist. If, by the time the law is implemented, there is no explicit fiduciary responsibility put on citizens, people will pass the blame of non-compliance and set a hollow precedent for universal recycling laws in other parts of the country. Although there are no comparable policies in the U.S., looking at the compliance rate of Seattle's voluntary organics diversion program (implemented in 2009) is informative. Although it is a consideration of dramatically different scales and cultures, the relatively small increase in organics at SWMEs in Seattle over the last 5 years illustrates that unenforced policies can only achieve so much. More recently, underwhelming compliance levels have caused the Seattle City Council to pass a new ordinance that goes into effect in 2015, which fines residents $1 per violation and businesses $50 per violation. Seattle Public Utilities (SPU) is the governing body in charge of enforcing the new ordinance. Incorporating this fine into the original organic materials management plan would not only have made the policy more effective, but also would have saved SPU and Seattle residents the headaches associated with a legislative amendment (BioCycle, 2014). Without explicit enforcement fines, Vermont may similarly fall short of 100% diversion of organics and recyclables from landfills.

What may become necessary is the establishment of additional law enforcement agents at ANR who are responsible for quality control. ANR may also find it necessary to establish officers who do random spot checks at transfer stations in order to determine whether municipal waste centers are complying with State Law. Vermont municipal waste centers, haulers, and citizens would benefit from an initial fine-enforcement description. If ANR outlines specific fines/withholding of government grants for municipalities, they will in turn ensure that their haulers (both dependent and independent companies) are bringing in well-separated waste, which can only happen when haulers threaten a surcharge or rejection of adulterated disposal bags. Pushing the solution all the way upstream to Vermont businesses and homeowners is the only way to truly enforce compliance with 148. The reason we have not seen this laid out yet is because public officials must make carefully calculated decisions when it comes to rules/legislation that could directly cost their constituents money. It is for this reason that the true responsibility for creating compliance has been pushed all the way down to solid waste facility managers and, eventually, haulers.

While it is clearly ANR's responsibility to enforce Act 148 in all its capacity, haulers are the component of this system that bridges the gap between individuals and waste management facilities, and therefore are poised to establish well-directed financial penalties on residents. Since haulers are the only people who consistently interact with upstream waste, they are a useful medium through which to educate citizens, but perhaps not a practical branch of the operation to enforce Act 148. According to the SWMEs and ANR advisors interviewed for this policy analysis, haulers in Vermont already do an excellent job of explaining changes in SWME policies. Since Act 148 already requires haulers to provide ANR with evidence for a variable rate

pricing plan, the onus should not also be on them (entirely) to enforce compliance with the law. Parts of the waste systems analyses clearly recommend teamwork between SWMEs and haulers because of shared enforcement responsibility. In the 2014 DSM report, for example, there is a wide-sweeping claim that solid waste alliances will lend financial and advisory assistance to haulers, but this has yet to be realized according to the Association of Small Haulers: “The VT DEC Solid Waste Program and Solid Waste Management Entities of Vermont (solid waste districts and alliances) will collaborate with haulers to provide assistance and information [about customers’] waste reduction needs” (DSM Report, 2014).

Costs

Currently, Vermont as a state has the capacity to effectively process approximately 22,000-35,000 metric tons of organic waste a year, which is approximately one half of the projected processing needs after Act 148 is fully implemented. By 2020, the need for off-site organic processing is projected to be closer to 44,000 tons per year (MMP, p.30). This disparity in current capability and projected processing need can be represented monetarily by a $20 million investment in composting infrastructure over the next six years (DSM, p.74). Figure 11 below shows the gradual increase in organics processing that is needed to supplant the existing infrastructure as the State works towards implementation of Act 148 by 2020.

Total Permitted Capacity of Existing Composting Facilites* (in tons per year, or TPY)

Source Date	Source	FOOD RESIDUALS	TOTAL ORGANICS
2013	DSM Systems Analysis	22,000	-
Oct-14	ANR Facility Permits (Legal)	15,000	60,000
Oct-14	ANR Est. Realistic Capacity	10,000	33,000-40,000

*Does not include composting facilities that are exempt from certification with Solid Waste Program; does not include farmers accepting food residuals as chicken or pig feed.

Total Organic Material Currently Being Processed at Composting Facilities (TPY)

Source Date	Source	FOOD RESIDUALS	TOTAL ORGANICS
2013	ANR Facility Reporting, 2013	4,805**	16,925

**Includes food scraps, food processing residuals, and mixed organics (food waste and other leaf and yard debris).

ADDITIONAL CAPACITY NEEDED:

Food Scraps	TOTAL
13,900 TPY	22,560 TPY

Committee should choose which estimates to use for basing cost

Total Off-Site Organic Material Processing Needs by Year† (TPY)

Year	Assumed Percentage of Generators Diverting	FOOD RESIDUALS	TOTAL FOOD, MIXED YARD, & COMPOSTABLE PAPER WASTE ††	TOTAL ORGANICS (estimate) †††
2014	5% Residents; 60% ICI generating 104+ tons/year of food waste	4,367	4,916	12,477
2020	60% Residents; 60% ICI	28,554	43,917	81,583
2022	60% Residents; 60% ICI	28,896	44,420	82,560
2022	*100% Residents; 100% ICI*	*52,998*	*84,073*	151,423

Figure 11: Breakdown of where additional capacity is needed for full implementation by 2020. (ANR, “Composting Facility Processing Needs,” 2014).

While estimations for this investment vary considerably, one thing is certain: municipalities will request far more funding for infrastructure improvements. On one hand, Act 148 lays out an aggressive and auspicious timeline, but on the other hand, it is difficult to raise

and distribute the capital needed to comply with such an aggressive timeline. As the (approximately) twenty million dollars in funding is raised by tax revenues and State appropriations, each solid waste district will be granted their own funds, with the autonomy to do with it what they please (Spencer, Personal Comm., 2014). The expectation of the State is massive investments in composting (and recycling) infrastructure but it is not earmarked towards any specific investment.

In addition to State appropriations, Act 148 will in theory generate a substantial amount of revenue for SWMEs due to the separation of retrievable waste. In fact (as mentioned earlier in this document) the CSWD came up with a foregone valuation estimate on recyclables & organics for 2009. Under perfect implementation of Act 148, assuming 2009 statistics, between seven and nine million dollars in recyclable and compostable materials will be reclaimed by municipalities. So, while SWMEs are doing a great job of directing State and municipal funds towards upfront costs, they stand to gain a return on their investment (or more accurately, on their grant) with widespread compliance. In other words, haulers that are a subsidiary of a municipality should be responsible for increasing convenience and strengthening infrastructure with upfront investment since they will be directly benefitting from the redirection of materials.

We recommend a government subsidy specifically for small haulers funded by a $1 increase in the franchise fee. This subsidy will come in the form of a low interest loan and provide funding for new trucks, truck retrofits, totes, and dumpsters. The Solid Waste Infrastructure Advisory Committee is currently reviewing, as of December 2014, the specific costs for organics collection in the state and will provide a more accurate estimation for the total amount of capital required for this fund.

Franchise Fee

While a number of proposals to generate capital for infrastructure investment are currently on the table, we identified an increase in the Franchise Fee as the most promising policy for generating the capital to help offset infrastructure and truck retrofit costs. Vermont's Solid Waste Franchise Fee, a surcharge applied to waste generated in the state of Vermont, has remained the same for 25 years. At $6/ton of waste, the franchise fee generates $3.5 million for the Solid Waste Management Assistance Fund, which is allocated to the implementation of the state solid waste plan, including implementation of changes and additions to the plan from year to year. The vast majority of the revenue generated (~75%) is dedicated to covering the costs of the existing solid waste management system. As Act 148 comes online over the next six years, changes to the state's waste management systems, namely increased infrastructure for organics collection and processing, necessitates that more funding become available for infrastructure investment, enforcement officers, etc. In raising the franchise fee by $1 dollar at current rates of disposal, the state would generate over $500,000/year in additional revenue at current rates of waste production. If that money gets earmarked for implementation and infrastructure investment, it would nearly double the amount of capital currently allocated for this purpose.

Stephanie Mack of the Vermont Smaller Haulers Association argues that increasing the franchise fee places the burden on hauling companies, who pay the fee when they empty their trucks (Personal Comm., 11/15/14). That said, as the bans under Act 148 begin to go into effect, increasingly more waste will get diverted from the landfill, decreasing the amount of revenue generated by the franchise fee. So although haulers will still pick up similar amounts of materials after the implementation of Act 148, most of the materials will get diverted from the landfill, reducing the burden of this proposed surcharge. In the late 1980s, Vermont established a capital

fund for solid waste infrastructure and equipment that did not include disposal. This fund provided the necessary infrastructure investment to establish Vermont's recycling system. The fund eventually ran out, but not after accomplishing its infrastructure goals. Act 148 necessitates a similar fund to make the recycling and organics diversion goals of Act 148 a reality.

Escheats

One possible funding mechanism is to escheat unclaimed bottle deposits to the state. Connecticut, Massachusetts, Maine, Michigan, and New York all have partial or full escheats programs established, which divert bottle deposits unclaimed by residents from beverage bottlers and distributors to the state. In 2011, unclaimed bottle deposits amounted to $33.5 million in Massachusetts and $17.8 million in Michigan (Bottle Bill). In Vermont, it is estimated that unclaimed escheats could generate $1.5 to $3 million in state revenue annually (VPIRG, 2003). This money would go a long way towards the estimated $20 million needed for infrastructure investment over six years. Additionally, as Act 148 begins to divert more recyclables and more bottles away from the landfill, materials management companies and SWMEs will begin to claim more bottle deposits. Instead of collecting escheats and redistributing the funds, the funds will end up directly in the hands of those that need the funds to begin with: small haulers, SWMEs, etc. Collecting escheats on unclaimed deposits would also decrease costs to taxpayers and avoid increases in the cost of waste management services. Figure 12 below shows a rough estimate of the total revenue for infrastructure development for four of the capital-raising tactics we investigated.

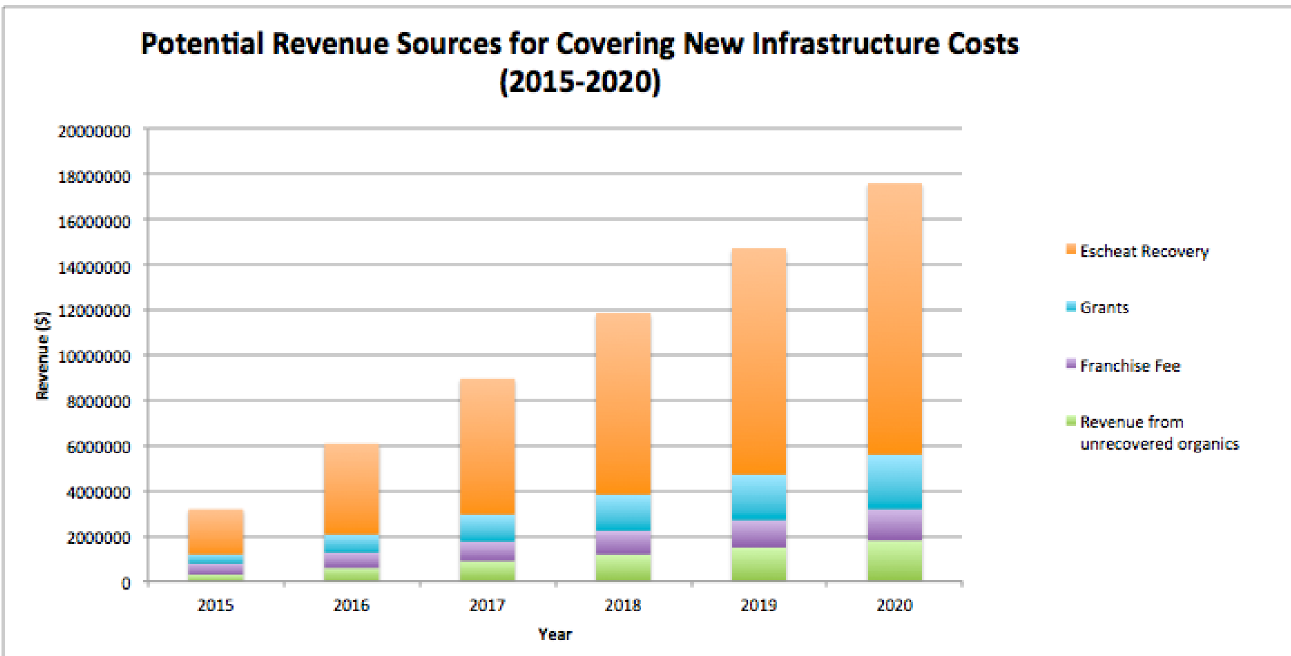

Figure 12: Revenue sources for infrastructure investment aggregated over six years based on anticipated yearly earnings. The revenue from the franchise fee grows at a depreciating rate anticipating the loss of revenue as tonnage of statewide waste decreases with the diversion of recoverable materials from the waste stream each year (Graph generated from the following data sources: VPIRG, 2014 & Bottle Bill, 2014 "Escheat Recovery"; ANR, 2014 "Grants"; ANR, 2014 & DMS Report, 2013"Franchise Fee").

Hauling Infrastructure

A large part of the Act 148 investments will fall on the state as Vermont attempts to build publically owned organics infrastructure. Yet because the SWMEs are built on public/private relationships, private waste hauling companies, composting facilities, sorting facilities, etc. will also have to invest in infrastructure in order to become compliant with the new standards of Act 148.

Part of the regulatory timeline for Act 148 is a gradual increase in what curbside haulers are responsible for picking up. Haulers must offer services for recyclables collection by 2015, leaf and yard debris by 2016, and food scraps by 2017. In Vermont, solid waste, recyclables, and organics are either collected by private haulers, collected by public haulers employed by Solid Waste Management Districts or municipalities or self-hauled by residents/much smaller business (DSM Report, 2014). By 2015, haulers will not be allowed to charge their clients separate fees for recycling and trash pickup, but there is no rule that says they cannot charge an extra fee for organics (DSM Report, 2014). This allows for a potential source of revenue to cover the cost of the additional tote bags, dumpsters, equipment retrofits, etc. that will be needed for compliance with Act 148.

According to Josh Kelly, Environmental Analyst for the Waste Management and Prevention Division within ANR, the staff began educating haulers across the state over the last year about the implications of Act 148 for business practices. Many small hauling companies currently lack appropriate equipment for picking up trash and recyclables so the transition to managing three separate materials streams will be a considerable jump. In order for haulers to pick up three separate materials at once, their truck must have three separate compartments. The organics storage area, which the majority of haulers lack, requires special construction that protects against seepage and odor. When you retrofit a truck to have one or two new compartments you also decrease the capacity of the existing one or two compartments. For each compartment to have enough capacity to run a normal route, a retrofitted truck may need a mechanical arm installed to lift waste bins up into the truck. According to Stephanie Mack of the Vermont Hauler's Association, most small companies would opt for a new/used truck already equipped to pick up organics rather than retrofit their existing fleet because of capacity issues and the special requirements for organics collection compartments (Personal Comm. 11/15/14) Organics pick up also requires additional bins and totes at the curb. Hauling companies, and by association SWMEs, are responsible for supplying those containers and it becomes an enormous expense for small haulers to supply all their clientele with bins.

It is difficult to measure exactly how much funding needs to be directed to small private haulers in Vermont. Small hauling companies fill a variety of niches managing the state's materials stream at a variety of scales with different equipment and infrastructure. As mentioned, some small hauling companies still do not offer recycling services. Still, knowing that most companies do not provide frequent, consistent organics pickup, we can assume they will have baseline equipment needs. A cost estimate of these needs is presented in Table 7.

Table 7. Estimated baseline costs for a small hauler in Addison County Waste Management District providing services to one third of residents and servicing 100 businesses or institutions. Said small hauler needs three truck retrofits and one new truck to come under compliance of Act 148. Based on ANR, Agency of Solid Waste Infrastructure Advisory Committee, 2014 estimates. Population: 36,791 (US Census Bureau) with Average Family Size: 2.42 (Index Mundi).

Item	Cost
New Truck	$175,000-$200,000
Truck Retrofit 1. Additional Compartment for Organics Pickup (3 Trucks) 2. Mechanical Arm for Lifting Dumpsters and Increasing Capacity (3 Trucks)	1. $180,000 2. $24,000
Totes for Residential / Small Commercial Pickup (5,000)	$250,000
Dumpsters for Commercial / Institutional Organics Pickup (100)	$60,000
Total	$689,000 - $714,000

The above cost estimate is based on SWME projections of costs of implementing Act 148 submitted to the Solid Waste Infrastructure Advisory Committee established under Act 175 in 2014 to:

1. "Review of the existing infrastructure to determine if sufficient to meet the facilities needed for managing mandated recyclables, leaf & yard residuals and food residuals required to be diverted from landfills by the Universal Recycling Law,
2. identify areas where infrastructure will be needed to meet the demand,
3. estimate the costs of the needed infrastructure, and
4. review options for funding needed infrastructure."

In Chittenden County, among eleven haulers, three do 91% of the business (Rose, "Pressing Pause on Consolidated Collection"). For businesses like Casella Waste Management and Myers, two of the largest hauling companies in Vermont, making the necessary adjustments, modifications, and retrofits to their trucks will be an investment, but it will not have the same impact as the investments made by smaller hauling companies (Mack, Personal Comm. 11/15/14). Small haulers across the state are worried about the implications of Act 148 and whether they will get outcompeted by larger businesses that can adapt (Shamlian, 2014). With infrastructure costs associated with Act 148 estimated at near $700,000 there is no question as to why they are worried. Without government subsidy the figure is a huge hit to small haulers if not an investment that would put small haulers across the state out of business. The nature of the organization of waste services at the SWME level also necessitates that small haulers exist to maintain operations as they are today. In areas like Chittenden County where an urban setting makes it possible for one hauler to tackle the waste collection needs of the whole region and remain financially stable, a loss of small haulers could have a negligible effect on access to curbside pickup and other waste management resources. But small haulers play a vital role in the

Solid Waste Management Plans that provide hauling resources to geographically isolated and sparsely populated areas.

Conclusion

As this report has discussed, new infrastructure costs for Act 148 are estimated to equal $20 million from investments in more compost facilities, anaerobic biodigestors, dumpsters, bins, forklifts, etc. Because this amount is not met by any current government appropriations, SWMEs will be expected to invest a lot of their own money. This paper conducted a comprehensive analysis of these costs and honed in on the projected costs to small haulers. What we identified as one of the most effective ways to raise capital for infrastructure development, including the subsidization of small hauler costs, was a one dollar increase in the existing $6/ton Franchise Fee. In their fiscal assessment of “Vermont Composting Facility Processing Needs,” ANR has projected that this surcharge increase would generate $500,000 a year. With the political aversion to any form of “taxes,” it can be difficult to find support for revenue-generating policies. For this reason, ANR must continue to work with its advisors and various partners to come up with innovative ways to raise capital and assuage the financial burden assumed by the various entities affected by Act 148.

Because ANR’s educational outreach programs will not get Vermont to its highest possible levels of compliance with Act 148, this section of our research has also highlighted the need for the roll-out of a fine-based system to help enforce compliance with this Law. The lack of financial enforcement mechanisms will make Act 148 operate like a voluntary program rather than a mandate. This will undoubtedly decrease its effectiveness, thereby undermining the goals established by Vermonters through their political representatives. But with explicit fiduciary penalties, this Law has the potential to bolster the culture of sustainability, and to pave the way for like policies across the country.

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Appendices

Appendix 1: Google survey about household composting habits in Middlebury and Burlington.

What town do you live in?
How do you manage your yard debris (grass clippings, leaves, stocks and stems, etc.)
Please check ALL that apply

- I put it in my home compost
- I drop it off in a composting facility
- I leave it to decay
- I put it in the trash
- Other:

What goes in your compost?
Please check ALL that apply

- Food
- Leaves
- Grass clippings
- Manure
- Other:

If you compost your food, where do you compost?
Please check ALL that apply

- I do not compost my food
- I have a composting pile or container in my house
- I drop off my waste at a municipal composting facility
- Other:

If you do not compost at home, where do you bring your compost? (Leave blank if not applicable)
Please provide the name and location of the facility, organization, or center
If you compost at home, how do you use your compost?
Please check ALL that apply

- I put it on my yard
- I put it on my garden
- I put it on my farm plots
- Inactive, I do not use my compost
- Other:

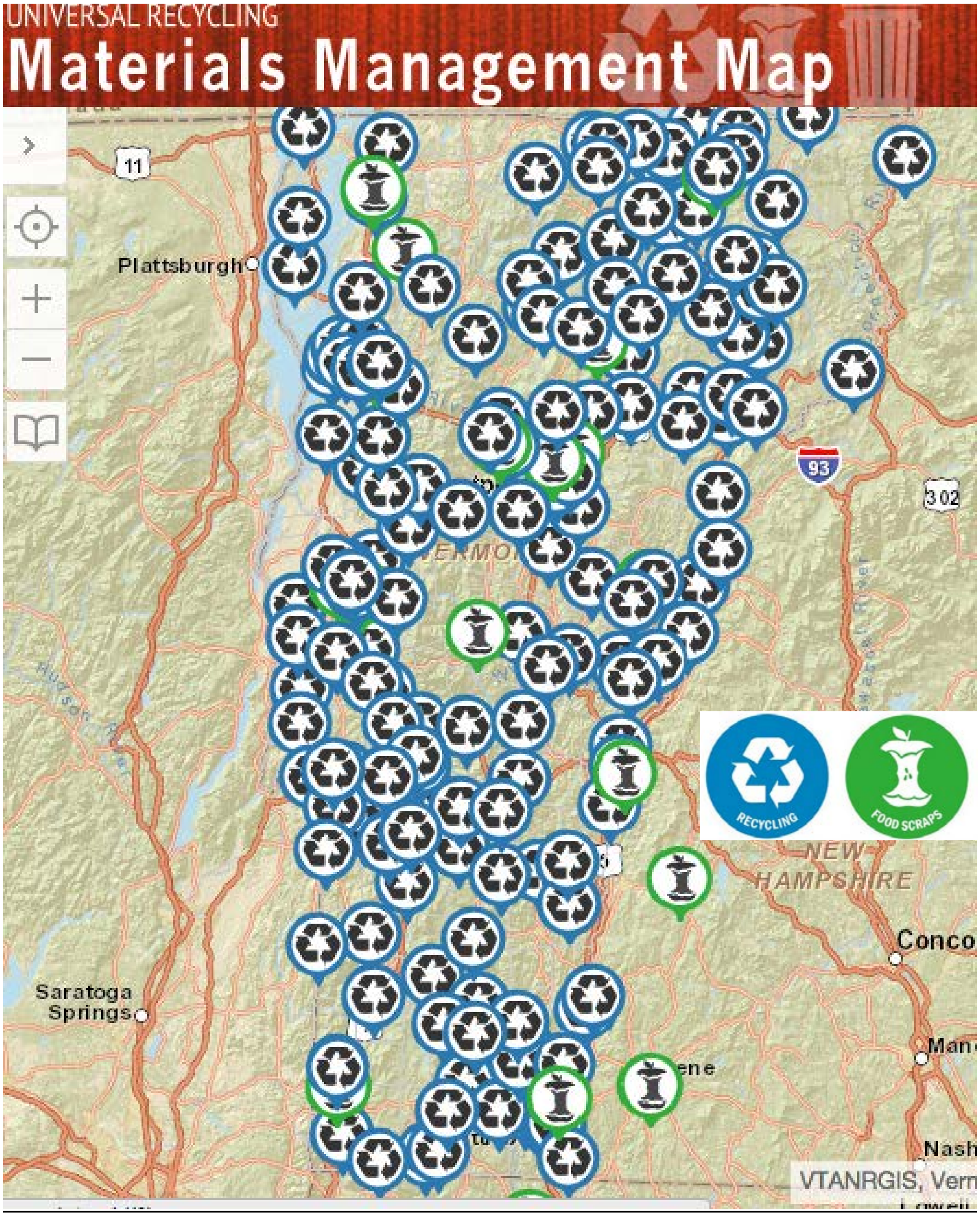
If you are willing to share your contact information with us please enter your email here.
If you opt to skip this question, it will not negatively affect our research in any way

Appendix 2: Questions asked to managers/employees of composting facilities in interviews

What is your compost primarily made up of?

- *Is all of your compost homogenous?*
- *Where do you get your ingredients? (How much/how often?)*
- *Where does your compost go after processing?*
- *Who is it distributed to?*
- *Is compost tested for contaminants?*
- *How often do you perform tests?*
- *Historically, have you experienced any issues with contaminants?*
- *If a contamination problem did arise, what is your protocol for mitigation?*

Appendix 3: The Agency of Natural Resources Universal Recycling Materials Management Map. Connects Vermont residents and business with waste management resources in their area.



Further Reading:

ENVS401 Senior Work: "Soils as an Exposure Pathway for Lead in VT"
<www.middlebury.edu/academics/es/work/communityconnectedlearning/envs0401/archive>

CHEM311 Methods Report: "Determining the presence of lead in soils and compost by Graphite Furnace Atomic Absorption Spectrometry and X-Ray Fluorescence"

Kate Bauman
CHEM0311

Abstract

Lead is a toxic metal known to cause deleterious effects on human health, particularly in children. When lead from paint and gasoline enter the environment, levels can exceed the safety recommendations of 300 ppm for compost and 400 ppm for soil. The health consequences associated with lead exposure indicate the need to determine environmental levels and the techniques to evaluate those levels. This study evaluated lead concentrations in the soil and compost of residential sites in the Middlebury, VT area by XRF and GFAAS. Lead concentrations decreased with increased distance from house walls, indicating that lead paint was contaminating the soil. Lead concentrations above safety limits were found closer than 90 cm to one house and 120 cm to the other, indicating that children's play areas should be at least 120 cm away, or that remediation techniques should be pursued. Compost lead concentrations varied widely (4338-5.6 ppm), but six samples exceeded safety limits. No significant difference was found in lead concentrations determined by XRF and GFAAS ($p = 0.17$), indicating that XRF, which is a faster technique, is equally effective as GFAAS and could be used for future *in situ* analyses.

Introduction

Lead is a toxic, naturally-occurring metal known to cause adverse health effects on multiple physiological systems.[1,2] This multi-targeted toxicity is particularly problematic for children because they absorb and retain lead more effectively than adults and are thus more susceptible to its neuropsychological effects.[1,3]No level of lead exposure has been determined safe for human health because even trace amounts of lead can result in dangerous blood levels with repeat exposure.[1]These adverse effects are worrisome due to the presence of lead in environmental sources such as soil, paint, and compost.

In Vermont, 69% of homes were built before the 1978 lead-paint ban, indicating that as houses deteriorate lead could contaminate the soil, resulting in a primary pathway of exposure for humans, particularly children, due to frequent contact.[4,5] The EPA recommends that soil lead levels not exceed 400 ppm in children's play areas.[6] Previous studies have found that lead levels decreased with increased distance from the lead source, but that unsafe blood lead levels in children resulted from lead in the soil surrounding small-town homes.[7–9] Despite these dangers, lead levels and patterns have not been evaluated in the soil surrounding lead-painted homes in Middlebury, VT to determine limits of play for children or establish safe management practices.

Safe management practices may also need to be developed for compost because previous research has found elevated lead levels in compost in the United States, Canada, and India.[10,11] In 2012, Vermont passed the Universal Recycling law (Act 148) that bans yard debris and food-

scraps from entering landfills by 2020 and relies instead on compost to dispose of organic waste.[12] Although the Vermont Agency of Natural Resources recommends a safety standard of 300 ppm of lead in compost, even trace amounts can contaminate crops and result in human exposure.[13, 14] Due to Act 148, baseline determinations of lead levels in compost in Vermont should be evaluated.

X-Ray Fluorescence (XRF) and Graphite Furnace Atomic Absorption Spectrometry (GFAAS) are commonly used techniques to determine heavy metal concentrations.[10,15,16] While GFAAS is an established and effective method with low detection limits, it requires the use of long acid digestion times. XRF has historically been viewed as a less sensitive method, but analysis can be performed without digestion.[17,18]These methods need to be directly compared to determine which is more effective for evaluating lead levels. Therefore, this study will compare XRF and GFAAS data in the determination of lead levels in soil and compost from the Middlebury, VT area to establish safe limits of play for children in yards, determine baseline compost lead levels, and evaluate XRF and GFAAS analytical methods.

Materials and Methods

Soil samples were collected from the top 5 cm of soil every 30 cm up to 300 cm from the wall of two homes built before 1978 in Middlebury, VT (11 samples/house). Compost samples were collected by shovel from 30 homes in western VT. Samples were massed, dried for 18 hours at 105 °C, homogenized, and packed into plastic XRF sample holders covered with Mylar film.

Soil and compost samples were analyzed for lead using a handheld Thermo Scientific (Waltham, MA, USA) Niton XLp 706A X-Ray Fluorescence Analyzer run on Bulk Soil Analysis mode (2 min/sample).

Approximately 0.1-0.15 g of sample were massed and placed into the Teflon beaker of a 4746 stainless steel Parr Acid Digestion Bomb with 2.5 mL of concentrated nitric acid. Acid digestion was performed by heating for six hours at 160 °C. After cooling, the samples were diluted based on XRF data to a concentration between 10-100 ppb.

Lead concentrations were determined using a PerkinElmer AAnalyst 600 (Waltham, MA, USA) graphite furnace atomic absorption spectrophotometer operated according to the manufacturer's recommended settings for lead. A diluent of 0.2% nitric acid was used as a blank and to make a non-linear forced through zero calibration curve with points at 10, 25, 50, 75, and 100 ppb. A matrix modifier of 3 μg $Mg(NO_3)_2$ and 50 μg $NH_4H_2PO_4$ was used for each sample and standard. Four reference Road Dust samples were analyzed, (BCR-773, 866 ± 16 ppm) and the average concentration was 830 ppm (96% recovery), thereby validating the analytical methods.

Results

Lead concentrations were determined by XRF and GFAAS for soil samples at increasing distance from two lead-painted houses in Middlebury, VT (Table 1). Although soil samples collected closer than 90 cm to the Ryan house and 120 cm to the Weybridge house exceeded the 400-ppm safety limit recommended by the EPA, lead concentrations decreased with increased distance from both houses (Figure 1).

While lead levels in compost determined by XRF and GFAAS were generally low, concentrations varied widely and six samples had concentrations above the 300-ppm safety

standard, as shown in Table 2. There was no significant difference in lead concentrations determined by XRF and GFAAS ($p = 0.17$) for all samples that had detectable levels of lead.

Table 1. Lead concentrations in soil determined by XRF and GFAAS at two houses in Middlebury, VT, USA.

	Ryan House		Weybridge House	
Distance from House (cm)	Pb by XRF (ppm)	Pb by GFAAS (ppm)	Pb by XRF (ppm)	Pb by GFAAS (ppm)
0	98	111	1379	1471
30	432	630	966	915
60	564	411	821	854
90	307	304	495	404
120	205	171	390	307
150	136	124	247	105
180	74	96	303	54
210	23.	43	228	147
240	nd[a]	31	155	107
270	nd	25	171	138
300	23	28	204	99

[a]nd indicates lead was not detected

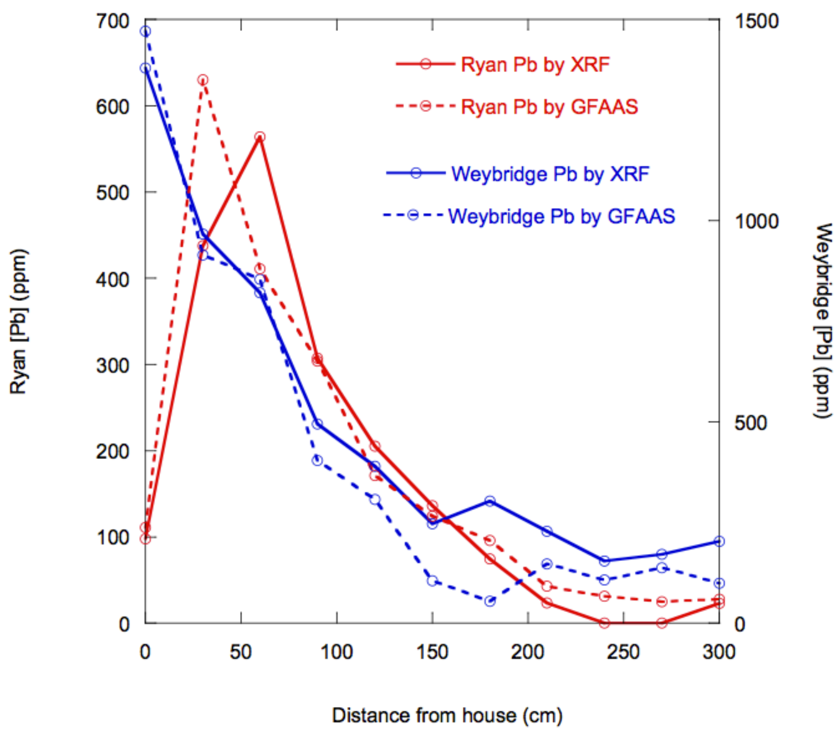


Figure 1. Lead concentrations in soil at varying distances from two houses in Middlebury, VT, USA determined by XRF and GFAAS.

Table 2. Lead levels determined by XRF and GFAAS in compost samples from the Middlebury, VT area.

Sample ID	Pb by XRF (ppm)	Pb by GFAAS (ppm)	Sample ID	Pb by XRF (ppm)	Pb by GFAAS (ppm)
276 SU003	4094	4338	1_005	34	32
68MAB001	625	660	42BIR_S_0920	34	35
16CROW_001	499	397	CHIT_002	22	186
276SU_004	409	323	CHIT_001	20	na
68MAB_002	391	na[a]	2318RR_001	18	30
16CROW_002	353	289	2401RR_001	nd[b]	15
68MAB_003	259	212	TBPLAT40920	nd	21
SWIL_002	193	156	CPG001	nd	37
SWIL_001	190	106	RyanCompost	nd	22
62OLD_002	93	70	MCCOM1003	nd	28
62OLD_001	91	35	MCCOM1002	nd	25
DT_001	42	32	1_001	nd	35
MM_002	42	43	1_006	nd	27
DT_002	38	25	1923 NW 001	nd	5.6
CPG_002	38	18	1923 NW 002	nd	9.3

[a]na indicates no measurements were taken
[b]nd indicates lead was not detected

Discussion

XRF and GFAAS analysis of soil and compost samples from the Middlebury, VT area found lead concentrations that exceeded safety standards, indicating the potential for harmful human exposure**.** Elevated lead levels close to house walls and decreased concentrations further away were expected based on past studies.[9] This suggests that chipped lead paint may be the source of contamination for surrounding soil and that children playing nearby are at risk for exposure. While the distances that contained lead levels above EPA standards differed between houses, the dangerous effects of even trace amounts of lead suggest that conservative management practices should be followed. Thus, children should play further than 120 cm from houses with lead paint, or remediation techniques like phytoextraction or soil-washing should be pursued to remove lead from soil.[19–21]

Although the majority of compost samples fell below the safety limit, six samples were found to have elevated levels, including one with visible paint chips that was more than ten times the recommended limit. When Act 148 is fully enacted, all residential compost will be combined in a single facility, so high levels of lead from a single residence could cause contamination of the entire site.[12] Previous research has found lead accumulation in vegetables grown in lead-contaminated soil which indicates that Vermont must find a way to remediate compost if it will be used as a crop amendment.[13]

There was no significant difference in the lead concentrations determined by XRF and GFAAS, demonstrating that both methods are equally effective at determining heavy metal

concentrations. XRF instruments, however, are portable and do not require sample digestion, thereby saving laboratory time and money. Past studies have shown the ability of XRF to perform accurate *in situ* field analysis, which should be studied further as environmental concerns become more time-sensitive and immediate results become more valuable.[18,22]

This study found lead concentrations that exceeded recommended safety limits in compost and soil samples from the Middlebury, VT area using GFAAS and XRF. These dangerous levels indicate that children are at risk for exposure and that remediation measures should be undertaken to prevent potential leading poisoning. XRF could be used for quick and effective analysis of more sites to better understand the patterns of lead distribution in the state.

Acknowledgements

Thanks to the Middlebury College ENVS0401 class for all field sampling and XRF data, the Vermont Department of Health, and all residents who allowed sampling from their homes.

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